

**“QUANTIFICATION AND COMPARISON OF ADHESIVE
REMNANT AND DEGREE OF ENAMEL LOSS AFTER
DEBONDING AND CLEAN UP UNDER TWO ADHESIVE
SYSTEMS USING OPTICAL COHERENCE TOMOGRAPHY -AN
IN VITRO STUDY”**

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CERTIFICATE

*This is to certify that **DR.SARAVANANAN.K**, Post Graduate Student (2013-2016) from the Department Of Orthodontics and dentofacial orthopedics, J.K.K. Nataraja Dental College, Komarapalayam, Namakkal District–638183, Tamilnadu has done the dissertation titled “**QUANTIFICATION AND COMPARISON OF ADHESIVE REMNANT AND DEGREE OF ENAMEL LOSS AFTER DEBONDING AND CLEAN UP UNDER TWO ADHESIVE SYSTEMS USING OPTICAL COHERENCE TOMOGRAPHY –AN IN VITRO STUDY** ” under my direct guidance and supervision in the partial fulfillment of the regulations laid down by THE TAMIL NADU DR. M.G.R MEDICAL UNIVERSITY, CHENNAI, FOR M.D.S BRANCH – V ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS. It has not been submitted (partial or full) for the award of any other degree or diploma.*

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One of the most significant advancement in the field of orthodontics was the introduction of enamel etching, adhesive resins and their use to bond orthodontic bracket onto the enamel surface of the teeth. With the advent of direct bonding technique, the old system of metal banding on each tooth for attaching brackets became obsolete.

At the completion of fixed orthodontic treatment, the ultimate goal of the orthodontist would be returning the enamel surface to as close as its original state as possible. Ideally, an orthodontist should try to minimize enamel loss at each stage right from initial pumice prophylaxis, etching, bonding, debonding, and clean up process and to restore the enamel surface with the same degree of smoothness and roughness.

The most popular bonding system in orthodontics has been based on Bounocore's technique of acid etching introduced in 1955, which has been used for many decades and it still goes on. Enamel loss during the acid etching technique depends on several factors like type of acid¹, its dissociation constant², its concentration and length of time³ it is in contact with the enamel surface.

The acid most commonly used in our day to day clinical practice for etching the enamel surface is 37% orthophosphoric acid, with an etch time of 15 to 30 seconds per tooth, in which case the enamel loss is typically in the region of 8.8 to 16.4 μm . Enamel loss reported so far showed wide variations from as little as 10 to 30 μm to as much as 170 μm .³

The development of adhesive systems have led to the creation of effective methods for bonding orthodontic brackets on enamel surfaces. In recent years, the introduction of Self-etching primers (SEPs) led to wide interests, leading to popular

use mainly due to their technique and ease of use. Apart from decreasing chair side time, minimizing the steps in bonding produces less error and reduce technique sensitivity. Studies by **Hosein et al⁴** and **Cal Neto et al⁵** have shown that self etching primers produce more conservative etching pattern and also reduced the enamel dissolution yielding shorter resin tags than conventional acid etch technique. This is one of the prime reasons why in this present study a comparison is made between self etch adhesive system and conventional etch adhesive system.

At the time of bracket removal, enamel loss can occur and it primarily depends on the type of bracket material and debonding technique. Numerous studies have shown that debonding of ceramic brackets led to undesirable enamel fracture, damage to the enamel and failure to debond. This risk has been shown to be reduced with metal brackets, but still a small degree of enamel fracture can occur because the nature of the bond is micromechanical between the composite resin bonding agent and the acid-etched enamel surface. Therefore, enamel loss is almost inevitable when the bond failure is at the adhesive enamel interface when viewed macroscopically.

The concern for enamel damage is especially critical when debonding ceramic brackets, but it is still used in the field of orthodontics primarily because of demand for esthetic alternatives to metal brackets. With many new generation ceramic bracket material and latest mesh designs, they also seem to lessen the extent of damage to the enamel on par with metal brackets⁶. But there are very few studies determining the nature of these new generation ceramic brackets on the enamel surface.

Residual adhesive on the enamel surface after debond can be removed in a number of ways. Though there are many methods to do the clean up to remove the adhesive remnant post debonding, the two most indicated clean up procedures are the

use of high speed tungsten carbide bur and low speed tungsten carbide bur. Several studies have shown that they not only minimize the enamel loss but also proved to decrease the amount of residual adhesive residue sticking on the enamel which later causes staining on the enamel few years after of completion of orthodontic treatment^{7,8}.

In a study, **Campbell et al**⁹ concluded that the materials that produced the best surface finish and with minimal enamel loss was a fluted tungsten carbide bur used in a high-speed handpiece, followed by rubber points and cups, a water slurry of fine pumice, and finally brown and green cups in a slow-speed hand- piece. **Zachrisson et al**¹⁰ showed that enamel loss is minimized with the use of a tungsten carbide bur in a slow speed handpiece.

Many qualitative and quantitative procedures have been developed to evaluate the amount of enamel loss and remaining adhesive after debonding the bracket and clean up. But precise quantitative data based on the comparison between the untreated and treated tooth surface were not found. So far, debondings were mostly examined by using optical profilometry and scanning electronic microscopes. However, recent methods like laser scanning, and atomic force microscopy have also been shown to only analyze the surface of the enamel.

One of the recently introduced methods, which allows the study of enamel both qualitatively and quantitatively is “**OPTICAL COHERANCE TOMOGRAPHY**” (OCT).

OCT is a non-invasive, non-radiative optical diagnostic tool based on Michelson's interferometer which is a optical imaging technique that uses low

coherence broadband near infrared light source that gives cross-sectional images of tissue microstructures.

Fujimoto et al¹¹ in 1991 was the first to introduce OCT in ophthalmology as a diagnostic tool and from then it has been broadly used in many other fields as a diagnostic tool like gastroenterology, gynaecology, cardiology, oncology, urology and dermatology.

In dentistry, OCT was used for anatomic characterization, caries diagnosis, evaluation of restorations, characterization of periodontal structures, and evaluation of integrity of dental sealants.

In orthodontics, it was first used to determine the qualitative markers of plaque bacteria around orthodontic brackets by **Garcez et al in 2011¹²** and the study regarding enamel surface changes by **Leos filho et al in 2013¹³** was the first one to give an in depth analysis and to quantify the layer of adhesive remnant after debonding.

OCT gives “optical biopsy” without the need for excision and processing of specimens as in conventional biopsy and histopathology. With development of optical specifications and technology, OCT shows its potential strength in research topics and clinical applications till date.

Previously, there were many studies done to evaluate enamel surface changes after debonding and they were mostly qualitative methods and dealt with only the enamel surface. However, there are very few reports in the literature where quantitative methods are used to analyze the enamel surface changes using OCT technique following debonding and clean up procedures¹³.

Therefore, the present in vitro study aims at using optical coherence tomography as a tool to quantify and compare adhesive remnant and degree of enamel loss after debonding and clean up under two adhesive systems.

AIM

To quantify and compare adhesive remnant and degree of enamel loss after debonding and clean up under two adhesive systems using optical coherence tomography.

OBJECTIVES

1. To quantify and compare the layer of remaining adhesive in area and depth after debonding between metal and ceramic brackets under self etch and conventional etch adhesive system.
2. To compare and determine the degree of enamel loss after debonding and clean up using low speed and high speed tungsten carbide bur.
3. To quantify and compare the layer of remaining adhesive in area and depth after clean up between low speed and high speed tungsten carbide bur under self etch and conventional etch adhesive system.

Faust and coworkers¹⁴ (1978) examined the penetration coefficients of thirteen direct bonding orthodontic adhesives. They concluded that the use of primers produced the highest penetration coefficient values. The primers tested were diacrylates, derived from Bis-GMA, modified to produce good wetting properties. They concluded that low viscosity resin could penetrate deeper into the etched enamel and form tag-like projections from 20 to 50 microns long.

Zachrisson and Arthun¹⁰ (1979) evaluated the quality of the enamel surface after debonding of brackets by stereomicroscopy and scanning electron microscopy. Thin diamond burs, coarse strips, medium and fine sandpaper, green rubber tip and tungsten carbide drill were tested and assigned to observable qualitative scores that ranged from 0 to 4 according to the index surface system: 0 = Perfect surface, 1 = satisfactory, 2 = surface acceptable, 3 = imperfect surface, 4 = unacceptable surface. They concluded that among the tested techniques the most appropriate results were obtained with tungsten carbide burs at low speed, producing standard results with less enamel loss and superior accessibility into anatomical grooves as other areas.

Mark Daniel Pus and David C. Way¹⁵ (1980) made a vitro study using steel reference markers in the enamel of 100 premolars. It was carried out in order to determine the enamel loss resulting from each step in the placement and removal of bonded orthodontic attachments. Measurements were made by using an optical profile projector for orientation and positioning, and a micrometer for quantification. The 10.7 μm of enamel lost during initial prophylaxis with bristle brush was greater than the 5.0 μm lost when a rubber cup was used, and the difference was statistically significant. A 90-second etch with phosphoric acid resulted in a mean loss of 6.9 μm , with no significant difference between liquid and gel forms. Rotary instruments, however, were required for cleaning up filled resin. Within this group, more enamel

was lost when the high-speed 7902 bur (19.2 μm) and green rubber wheel (18.4 μm) were used than when the low-speed 7111 bur (11.3 μm) was used. Total enamel loss ranged from 26.1 to 31.8 μm for unfilled resin and from 29.5 to 41.2 μm for filled resin, depending on the instrument used for prophylaxis and debonding.

Zachrisson et al¹⁶ (1980) using fiber-optic transillumination made a clinical assessment of enamel cracks in three groups of adolescents representing debonded, debanded, and orthodontically untreated teeth. The findings indicated that enamel cracks were extremely common in all three groups. Most cracks were not very prominent and could easily be overlooked on routine clinical examination. Clinical implications of the observations are (1) careful bonding and debonding do not result in a significant increase of enamel cracks; (2) whenever pronounced vertical cracks occur on other teeth than maxillary central incisors and canines or many horizontal cracks are observed, the bonding/debonding technique should be re-evaluated; (3) it seems advisable to notify parents/ patients of marked cracks before orthodontic treatment is started, in order to avoid problems later when it is difficult or impossible to document their pretreatment existence.

Peter Diedrich et al¹⁷ (1981) determined the central problem of the direct bonding technique with a scanning electron microscope study. Extracted teeth were etched for the study starting from the appearance of a two minute etching with 50 percent phosphoric acid, the influence of different factors on the etching pattern were investigated based on variation in etching time, rinsing time. The penetration depth of resin tags was measured by means of adhesive matrices and cross sectional images of the bracket /enamel/adhesive interface. He concluded that the location of the fracture site depends on the strength of the micromechanical retention produced by acid etching.

Robert Edward Thompson and David C Way¹⁸ (1981) did an in vitro study using steel reference markers in the enamel of permanent premolars to determine the enamel loss during prophylaxis and multiple bonding/debonding procedures. Before bonding, one group received prophylaxis and acid etching and the other group did not, and the multiple bonding and debonding procedures were conducted with filled and unfilled resin adhesives. They concluded that total enamel loss was significantly more in the groups where etching and prophylaxis was done in both filled and unfilled resin groups.

Rouleau et al¹⁹ (1982) did a study on enamel surface after clinical treatment and removal of orthodontic brackets. Forty-five orthodontically treated teeth were evaluated after removal of brackets and heavily filled bonding resin, using three basic procedures. Eleven raters ranked the photomicrographs on the basis of apparent smoothness of the replicated enamel surface. They found significant differences were found between the three removal techniques. They finally concluded that enamel surface roughness decreased with the removal technique in the following order :(1) hand scaler (2) twelve fluted carbide bur (3) ultra fine bur.

Shey and Brandt²⁰ (1982) said that when enamel loss associated with acid etching for bonding attachments is investigated, one dimensional yardstick for determination of enamel loss is not adequate to quantify the enamel loss, the method of choice should consider the heterogeneity of enamel. Since the enamel does not etch uniformly, the use of conventional method to assess the depth reported by other investigators will reveal only part of the true topographical changes that have occurred. They concluded that a method of quantifying the calcium mass as a byproduct of enamel dissolution and computing enamel loss and depth of etch will give the realistic area on how much of enamel is lost.

O'Brien et al²¹ (1988) did a study to test the theory that there is a relationship between bond strength at the separate interfaces of the direct bonding system and the amount of residual debris on the enamel surface following bond failure. They applied shear loads at adhesive/enamel and adhesive/bracket base interfaces using a chemically cured and visible light cured materials with two types of bracket bases. They concluded that the amount of residual debris following removal of bonded bracket is not related to the shear bond strength at separate interfaces but is governed by factors caused by bracket base design and properties of adhesive used.

Jan Odegaard and Dietmar Segner²² (1988) compared shear bond strength of metal brackets with a new ceramic bracket. He took one hundred bovine teeth and bonded with two types of metal and a new ceramic bracket for comparison. Two adhesives were used, so called no mix and paste/paste adhesive. The shear bond strength of the ceramic bracket was found to be superior for both adhesives. Bond failure was found to occur for ceramic brackets in the enamel/adhesive interface and for metal brackets in the bracket/adhesive interface. The study concluded that bond strength between the ceramic bracket and the adhesive in the shear mode is stronger than that between adhesive and enamel.

P L Sadowsky et al²³ (1990) conducted an in vivo study to determine the effect of etchant concentration and duration of retention of orthodontic brackets. Two randomly selected groups of orthodontic patients participated in the study. They found that reducing the etching time of 37 % phosphoric acid from 60 seconds to 15 seconds or reducing the acid concentration from 37% to 15% for 60 seconds had no significantly different effect on the retention of bonded orthodontic attachments. The result they showed suggested that reduction of etchant concentration and duration of etching should be considered.

Thomas bredd and Prasanna kumar shivagupta²⁴ (1991) did a SEM study to determine the extent of enamel damage caused by debonding ceramic brackets, and compared the enamel damage difference between ceramic and metal brackets post debonding and also compared the effects of different types of retention the ceramic bracket had. Then they concluded that ceramic brackets damage more enamel than metal brackets and those brackets, which had mechanical retention, caused less damage when compared to chemical retention.

Wei nan wang and tz chau lu²⁵ (1991) tested the bond strengths of various etching times 15,30,60, 90 and 120 seconds with 37% phosphoric acid on fifty extracted premolars from 9-16 year old children. The tensile bond strengths were tested with an Instron testing machine. The results for 15,30,60,90 were not statistically significant and for the 120 second etching time the decrease in bond strength was significant. Enamel fragments increased in proportion with the length of the etching time. They finally concluded that the optimal time for etching is 15-30 seconds.

Wolfgang Carstensen²⁶ (1992) studied the effects of different acid concentrations on the enamel surface morphology. He had taken 25 extracted premolars from young patients and etched the buccal surfaces with 40%, 20%, 10%, 5% and 2% phosphoric acid solutions for 60 seconds. They concluded that great variation of the etching pattern was observed in almost all test groups and the extent of prism outlines were smaller in the cervical region and at a lower acid concentration.

Krell et al²⁷ (1992) examined the effects of ultrasonic orthodontic bracket removal and cleanup. They compared them with conventional debonding and cleaning of the enamel surfaces with burs and polishing disks. The amount of enamel loss and

time for bracket removal and clean up were also addressed. The results of this study was that (1) enamel loss as a result of orthodontic bracket removal is minimized by first removing the bracket with the debonding plier, followed by ultrasonic removal of the residual composite; (2) the tooth surface was not significantly affected when using either the combined debonding plier and cleaning with ultrasonic clean up technique or the ultrasonic debonding (3) using the debonding plier followed by ultrasonic removal of the residual composite required significantly less time when compared to other techniques.

Leonarda foresti soares de menezes and Orlando chevitaresh²⁸ (1994) did a study to find out whether the presence of sealant and viscosity of the resin had an influence on the formation of resin tags. Twenty-four extracted molars were randomly divided into six groups of four. Three resin viscosities were applied with and without sealant and resin tag formation was studied under scanning electron microscope. They found that statistically significant larger resin tags was shown in the group using the more fluid composite resin when in combination with the sealant, although the frequency, regularity and form of tags did not differ significantly among the various viscosities.

Hong et al²⁹ (1995) compared tungsten carbide burs and evaluated four other methods of enamel remaining index by scanning electron microscopy analysis. After bracket debonding, the samples of each group were finished by different methods: Ormco bracket remover pliers, tungsten drill (Komet) at low speed, ultra high speed diamond drills, tungsten drill at high speed, white stone finish. They demonstrated that there was no significant difference in inter-observer variability in the two assessments. They concluded by saying that no isolated method was considered ideal for removal of the remaining composite.

Campbell et al⁹ (1995) evaluated the enamel surface under scanning electron microscope (SEM) following debonding of orthodontic attachments and removal of excess resin with green stone, diamond bur, sharp band remover, tungsten carbide bur and abrasive disc. He concluded that 30 fluted tungsten carbide bur found to be the efficient method of removing resin from enamel surface and produced least amount of scarring.

Zarrinnia et al³⁰ (1995) performed scanning electron microscopy analysis of the enamel surface following different debonding protocols. Forty two extracted premolar teeth were divided into seven groups. SEM images before bonding were taken and the teeth were bonded according to standard protocol. Following bracket removal, different debonding procedures were performed on each group of teeth as follows: Group 1) Fine finishing diamond point bur operated at high speed, Group 2) 169L carbide bur, Group 3) 12 fluted carbide finishing bur, Group 4) A stainless steel finishing bur, Group 5) Moore disks used sequentially from coarse to fine, Group 6) SofLex disks used sequentially, and Group 7) Shofu wheels. Rubber cups and Zircate paste were used on all groups as the final step.

Based on their findings, Zarrinnia et al recommended using a 12 fluted tungsten carbide as the first step following bracket removal followed by the SofLex disks and a final finishing with a rubber cup and Zircate paste.

Pramod.k.Sinha and Ram S Nandha³¹ (1997) studied the effects of different bonding and debonding techniques on debonding ceramic brackets in 180 freshly extracted bovine teeth where they divided it into two groups based on the type of bracket employed(monocrystalline and polycrystalline) and the brackets were bonded with the direct and two indirect bonding methods(modified Thomas and the one that

used thermal cured resin). Each bonding group was further divided into groups of 10 based on the type of debonding technique (lift off ,delamination and twisting). The study concluded that both bonding and debonding techniques have significant effect on bracket failure and ARI scores. They found that debonding ceramic brackets using delamination technique of debonding combined with thermal cured indirect bonding technique proved to be inexpensive and safe method for both types of ceramic brackets.

Van Waes et al³² (1997) evaluated the loss of enamel in six premolars, extracted due to orthodontic reasons using computerized 3D scanner with 1-micrometer resolution by performing 2646 measurements. They compared the loss of enamel before and after the procedure of bonding and debonding. The removal of residual resin was done using a tungsten carbide bur so that the results were not interfered with the study, concentrating only on the enamel loss and not relating to the residual composite. They found out that there was a limited loss of enamel when tungsten carbide burs were used cautiously. An average enamel loss of only 7.4 micrometer was observed in this study.

Bishara et al³³ (1998) did a study on extracted human teeth to determine the effects on the shear bond strength and the bracket adhesive failure mode when an acidic primer and other enamel etchants were used to condition the enamel surface before bonding. In group 1 brackets were etched with 37% phosphoric acid and bonded with a adhesive, group 2 were etched with 10% maleic acid, in group 3 an acidic primer that contains both the acid (phenyl-p) and primer (hema and dimethacrylate) and a lightly filled resin was used as the adhesive, in group 4 same acidic primer as in group 3 but a highly filled resin was used as adhesive. The results indicated that group 4 provided clinically acceptable shear bond forces and it was

comparable with group 1 and group 2 but group 3 had significantly lower shear bond force. It was also noted that group 4 produces least adhesive remaining on the tooth after debonding thus reducing clean up time.

Ogaard B et al³⁴ (2001) analysed the oral microbiological changes, long-term enamel alterations due to decalcification, and caries prophylactic aspects and concluded that 1) conventional etching with phosphoric acid induces relatively severe adverse effects on enamel surfaces and there is a potential risk for resin tags even after debonding and cleanup. 2) Resin remnants in surface enamel can discolor and produce an unaesthetic appearance of labial enamel after debonding.

Bishara et al³⁵ (2001) assessed the effect of a self etch primer on shear bond strength and compared this to conventional etch and priming in vitro. Brackets were bonded to extracted human teeth according to 1 of 2 protocols. In the control group, teeth were etched with 37% phosphoric acid. After the sealant was applied, the brackets were bonded with Transbond XT and light cured for 20 seconds. In the experimental group, a self-etch acidic primer was placed on the enamel for 15 seconds and gently evaporated with air, as suggested by the manufacturer. Findings indicated that the use of a self-etch primer resulted in a significantly ($P = .004$) lower, but clinically acceptable, shear bond force (mean, 7.1 ± 4.4 MPa) as compared with the control group (mean, 10.4 ± 2.8 MPa). By comparing the adhesive remnant index scores they concluded that there was significantly ($P = .006$) more residual adhesive remaining on the teeth that were treated with the self-etch primer than on those teeth that were bonded with the use of the conventional adhesive system.

Yamada et al³⁶ (2002) analyzed the effect of using self-etching primer for bonding orthodontic brackets using (FE- SEM) and pertaining to the fact that there

were no previous reports on the efficacy and shear bond strength of self-etching primers with resin-modified glass ionomer cements for bonding orthodontic brackets in orthodontic dentistry. Resin-modified glass ionomer cement used with Megabond self-etching primer gave no significantly different shear bond strength compared with polyacrylic acid etching. At the same time composite resin adhesive used with Megabond self-etching primer gave significantly lower shear bond strength than phosphoric acid etching. FE-SEM observation revealed that Megabond self-etching primer produced less dissolution of enamel surface than did phosphoric acid and polyacrylic acid etching. Finally they concluded that Megabond self etching primer may be a candidate for bonding orthodontic brackets using the resin-modified glass ionomer cement for minimizing the amount of enamel loss.

Bishara et al³⁷ (2002) of this study was to assess and compare the effects of self-etching primers, including a fluoride-releasing primer, on the shear bond strength of orthodontic brackets bonded to extracted human teeth using four protocols. Group 1 (control), teeth were etched with 37% phosphoric acid, group 2, a self-etch acidic primer (3M ESPE Prompt L-Pop, St Paul, Minn), group 3, an experimental self-etch primer EXL #547 (3M ESPE), group 4, a fluoride-releasing self-etch primer was applied and bonded with One-Up Bond F (J. Mortia, USA Inc, Irvine, Calif) whereas others were bonded with transbond XT and all using manufacturers instructions. The results showed that One- Up Bond F (mean strength, 5.1 ± 2.5 MPa) and Prompt L-Pop (strength, 7.1 ± 4.4 MPa) had significantly lower shear bond strengths than both the EXL #547 self-etch primer (strength, 9.7 ± 3.7 MPa) or the phosphoric acid etch and the conventional adhesive system (strength, 10.4 ± 2.8 MPa).

Ingrid Hosein et al⁴ (2004) compared the enamel loss at each stage of the bonding and debonding process by using self-etching primer with conventional two-

stage etching and priming process with 37% phosphoric acid. He observed loss was much less than in previous reports on enamel loss after acid etching. With the self-etching primer, the median enamel loss was significantly lower, at 0.27 m (range, 0.03 to 0.74 m). At debond, there was also a significant difference in the adhesive remnant index scores between the 2 groups, with more adhesive remaining on the enamel surface in the conventional-etch group. It was during enamel clean up that most surface loss occurred. The study concluded that in both the conventional and self-etch groups, most enamel loss occurred after the use of the high-speed tungsten carbide bur or the ultrasonic scaler and least with the slow-speed tungsten carbide bur or the debonding pliers.

Ireland et al³⁸ (2005) did a study was to determine whether there was any difference in the degree of enamel loss at bond-up, debond and enamel clean up using two different adhesive systems and four different methods of enamel clean up. The adhesive systems were 37 per cent *o*-phosphoric acid with Transbond XT (group 1) and 10 per cent poly (acrylic acid) conditioner with Fuji Ortho LC (group 2). The four clean-up methods were a high-speed tungsten carbide bur, a slow-speed tungsten carbide bur, an ultrasonic scaler and debanding pliers. He concluded that the lowest enamel loss was observed with the poly acrylic acid conditioner group, Fuji Ortho Light cure system group and where enamel clean up was performed using the slow-speed tungsten carbide bur.

Cal-Neto et al⁵ (2006) analyzed the effect of a self-etching primer (Transbond Plus SEP, 3M Unitek), developed for orthodontic use, in the regularity and depth of adhesive infiltration in the enamel of human permanent teeth and to compare it with phosphoric acid using scanning electron microscope (SEM). Their results demonstrated that the SEP was more conservative and produced a smaller amount of

demineralization and less penetration of adhesive in the enamel surfaces when compared with the conventional phosphoric acid system.

Morten Fjeld and Bjørn Øgaard ³⁹ (2006) investigated the effects of conventional etching with a 35% phosphoric etching gel and priming/bonding with Transbond XT primer/adhesive (3M Unitek), conditioning with 10% polyacrylic acid and bonding with a resin-modified glass ionomer cement (Fuji ORTHO) or using a self-etching bonding system (Transbond Plus) and bonding with Transbond XT adhesive on the surface morphology of the enamel. They concluded that bonding systems with self-etching primers or conditioners with polyacrylic acid might offer potential benefits compared with conventional acid etching and priming because of fewer irreversible changes to the enamel surface.

Neslihan Eminkahyagil et al⁴⁰ (2006) studied the effect of Resin-removal Methods on Enamel and Shear Bond Strength of Rebonded Brackets. A total of 80 premolars were included in the study and the remnant adhesives were cleaned with four methods: (1) low-speed tungsten-carbide bur (TCB), (2) high-speed TCB, (3) Sof-Lex finishing disks, and (4) microetcher. He concluded that resin removal with high-speed TCB was the quickest procedure and it represented the most hazardous enamel scars. SofLex disc showed a decrease in surface irregularities, but it was the highest time-consuming method, and there were too many remnants on the enamel surface. They concluded by saying that scarring of enamel after debonding is inevitable but can be reduced.

Habibi et al⁴¹ (2007) compared the debonding strengths of one metal and two types of ceramic orthodontic brackets with different retention mechanisms bonded to enamel and to determine the risk of enamel damage after debonding. 36 maxillary

premolars were divided into 3 groups: metal, ceramic with chemical retention, and ceramic with mechanical retention and were bonded to the teeth with a luting resin composite. There were significant differences in the adhesive remnant index scores between metal and chemically retained ceramic brackets, and between chemically and mechanically retained ceramic brackets. They finally concluded that risk of enamel damage when debonding ceramic brackets is not greater than the risk when debonding metal brackets.

Amna Hassan Al Shamsi et al⁴² (2007) did a study to evaluate 3-dimensionally the changes on tooth surfaces after debonding orthodontic brackets and after removing residual adhesive and finishing. Sixty premolars were randomly divided into 2 groups, and brackets were bonded according to the manufacturers instructions and two types of orthodontic adhesives were used. Models were made of each tooth before bonding, after debonding, and after removal of residual adhesive. The models were scanned with a 3-dimensional laser-scanning machine, and the scanned images were analyzed by using modified analytical software. The study concluded that adhesive thickness and enamel loss due to orthodontic procedures can successfully be measured in vitro by using three-dimensional laser scanning technology.

Ekaterini Paschos et al⁴³ (2008) did a test to find out that there is no difference in the bond strength with or without contamination with artificial saliva when using two different self-etching primers in comparison with a conventional acid-etching method for bonding of orthodontic brackets. One hundred fifty extracted human premolars were randomly allocated to six different groups, bonding with 25 teeth in each group. Debonding was done with a universal testing machine. The load was recorded at bond failure and the location of adhesive failure was determined

under magnification using the adhesive remnant index (ARI). They concluded that saliva contamination significantly decreased the bond strength when the conventional acid-etching method was used and the self-etching primers were influenced the least. They also found that the bond strengths achieved for the self-etching primers and the conventional etching method after saliva contamination were not significantly different.

Chen-Sheng Chen⁴⁴ (2008) did a study to determine the location and size of enamel fracture (EF) when debonding a bracket and concluded that the enamel fracture locations coincided with the areas where the tensile, shear, or torsion force was exerted. Therefore, the dentist should give extra care and attention to these specific areas of enamel after debonding. The sizes and incidences of enamel fracture produced by these three debonding modes showed no significant difference. Thus, clinically, when the sizes and incidences of produced enamel fracture are considered, it should not matter which of these three exerting forces is used to debond a bracket.

Marcus Holzmeier et al⁴⁵ (2008) studied the shear bond strength (SBS), etching pattern and depth, and debonding performance of several market-leading self-etching (SE) adhesives, primarily used in restorative dentistry and compared with conventional etching. SEM examination revealed less distinctive enamel-etching patterns for self-etching products than for phosphoric acid etching. CLSM analysis revealed etching depths between 0.5 and 20 μm depending on the product. When self-etching products were used, less residual composite remained on the enamel surface than after phosphoric acid etching. They concluded that all adhesives tested are suitable for bonding orthodontic brackets and they reduce the risk of enamel fracture minimizing etching depth, which in turns means less conditioning related enamel loss.

Montasser et al⁴⁶ (2008) studied the adhesive systems for bonding orthodontic brackets where two self-etch primers [Transbond and M-Bond] and a conventional phosphoric acid etch [Rely-a-Bond] was used. He showed, whether it would show a difference with respect to rebonded enamel surface morphology and chemical composition. The etching of the two self-etch groups is less aggressive and less uniform than that of phosphoric acid. The results confirm the original hypothesis that differences in adhesive systems are manifested in less aggressive etches and less adhesive left on the enamel surface for the self-etching adhesive systems.

Ulosoy et al⁴⁷ 2008 did a study to evaluate (1) the effectiveness of one-step polishers on the surface morphology of enamel using scanning electron microscope (SEM) and compared their effects with conventional systems for residual adhesive removal; and (2) the time spent to remove resin remnants. The result of the study showed that 30-blade tungsten carbide burs were the least time consuming procedure and the best system in SEM analysis was the PoGo micro-polishers followed by Super-Snap Rainbow system. They concluded that the effect of polishing systems on residual resin removal was dependent on the characteristics of the instruments in each system. They also said that 12- and 30-fluted TCB at high speed and water coolant proved to be fast and efficient in residual resin removal, but the resultant enamel surface with enamel scars needs to be finished by other polishing techniques.

Shinya horiuchi et al⁴⁸ (2009) did a study to evaluate the effectiveness of two self-etching and two phosphoric acid-etching orthodontic adhesives for enamel by bonding orthodontic brackets on human premolars ($n=10$ for each adhesive). Ten teeth without bracket bonding, were used as control for SEM observation. Bracket-debonding force by means of debonding pliers, adhesive remnant index (ARI), and enamel surface morphology were examined. All the Adhesives they tested exhibited

sufficient bond strength for clinical use and the two acid-etching adhesives caused considerable demineralization. They finally concluded by saying that the action of self-etching systems was evidently more conservative causing less demineralization.

Brauchli et al⁴⁹ (2010) did a study to evaluate the roughness of the enamel surface after different conditioning and polishing procedures. 42 bovine incisors were submitted to conventional abrasion (using 37% phosphoric acid), to air abrasion, and a combination of the two. Brackets were put in place and then debonded, and the remaining adhesive removed with a carbide bur or via air abrasion. The enamel surface's roughness was assessed using a confocal laser-scanning microscope (CLSM). The study concluded that the method of enamel conditioning revealed no significant effect on the enamel surface after debonding. Neither polishing via air abrasion nor carbide bur resulted in differences in superficial roughness. However, the carbide bur left a wave-like pattern on the enamel surface, but due to its efficiency and easy manageability, they recommend removal with the carbide bur.

Ozer et al⁵⁰ (2010) did a study to examine tooth surfaces restored with different cleanup protocols. Ninety-nine premolars extracted for orthodontic purposes were used and the two materials tested were Sof-Lex disks and fiberglass burs. These were used alone and in combination with high- and low-speed handpieces, with which they were also compared. Eight groups were tested with each group having ten samples. They were examined with profilometry and scanning electron microscopy. The time required for the cleanup processes were also recorded. They showed that Sof-Lex disks and fiberglass burs required more time than carbide burs but did not result in significantly longer times for the cleanup procedure when combined with tungsten carbide driven by low- or high-speed handpieces or when used alone with low-speed handpieces. They concluded that no clean up procedure used in this study

restored the enamel to its original roughness. The most successful was Sof-Lex disks, which restored the enamel closer to its original roughness.

Knosel et al⁵¹ (2010) evaluated impulse debonding compared to three conventional methods for bracket removal in relation to the damage caused to the enamel surface. Ninety-six osteotomed third molars were randomly assigned to two study groups for bracket bonding with either a composite adhesive system (CAS) or a glass ionomer cement (GIC). These two groups were then each randomly divided into four subgroups according to the method of debonding using (1) bracket removal pliers, (2) a side-cutter, (3) a lift-off debracketing instrument, and (4) an air pressure pulse device. No significant differences were found between the two different types of adhesives in terms of the amount of damage to the enamel. Portions of enamel damages found for impulse debonding were 0%, bracket removal pliers 4%, lift-off debracketing instrument 17%, side cutter 21%. They concluded that Impulse debonding provides a good alternative to conventional debonding methods.

Sull et al⁵² (2010) did a study to report normal macular thickness measurements and assess reproducibility of retinal thickness measurements acquired by a time domain optical coherence tomography (OCT) and two commercially available spectral / Fourier domain OCT instruments (RTVue-100 and 3D OCT-1000). Forty randomly selected eyes of 40 normal, healthy volunteers were imaged. Subjects were scanned twice during one visit and a subset of 25 was scanned again within 8 weeks. Retinal thickness measurements were automatically generated by OCT software and recorded after manual correction. They finally concluded that Commercial spectral / Fourier domain OCT instruments provide higher speed and axial resolution than the Stratus TD-OCT, although they vary greatly in scanning protocols and are currently limited in their analysis functions.

Sevinc Karan et al⁵³ (2010) tested the hypotheses that (1) there is no significant difference between the effects of two burs on the surface roughness of enamel after orthodontic debonding, and (2) there is no difference between resin removal times of the two burs. They concluded that after orthodontic bonding, the composite bur used for resin removal creates smoother surfaces compared with the carbide bur even smoother than original surfaces. They also said that application of a composite bur is more time consuming than use of a carbide bur.

Sacha Ryf et al⁵⁴ (2012) did an in vitro study to evaluate the enamel loss and adhesive remnants following bracket removal and various cleanup procedures. The cleanup was carried out with five different procedures where carbide bur was used in one group and carbide bur was combined with various polishing kits in other groups. Silicone impressions were made at baseline, after debonding and polishing to produce plaster replicas. The replicas were analysed with a three-dimensional laser scanner and measured with analytical software. They concluded that Multi-step rubber polishing kits seemed to have advantages in preventing enamel loss and clean up procedures with carbide burs may only result in the removal of too much tooth substance. They also pointed out adequate clean up without enamel loss is difficult to achieve.

Simona-Delia Tsu⁵⁵ (2013) in a review showed that Optical coherence tomography (OCT) allowed the visualization of the retinal microarchitecture as cross-sectional or tomographic volumetric data. It was used as the most precise method to measure the central macular thickness (which is the most important practical parameter) in vivo and it was demonstrated that there are differences in the retinal thickness measurements between OCT models, explained by higher axial and transverse resolutions. He also said that technological progress in OCT imaging

rendered new perspectives for better understanding of the retinal diseases, opening new avenues for the fundamental and clinical research.

Leao Filho et al¹³ (2013) demonstrated the potential of the optical coherence tomography technique on the evaluation of changes and damages in the enamel structure caused by debonding and cleanup procedures. The analysis of the 2-dimensional and 3-dimensional images obtained with optical coherence tomography allowed observation and evaluation of adhesive remnants, enamel damage, and superficial aspects of enamel from different methods of adhesive remnant removal. The 2-dimensional optical coherence tomography analysis allowed in-depth observation of the adhesive remnant layer. They concluded that Optical coherence tomography can be a powerful tool for academic and clinical applications for the evaluation of debonding procedures.

Robert Koprowski et al⁵⁶ (2014) used optical coherence tomography (OCT) as one of the assessment methods for the measurement of enamel thickness and did a 3D reconstruction of image sequences fully automatically. 180 OCT images of teeth using Topcon 3D OCT-2000 camera were obtained in vitro by performing sequentially 7 stages of treatment on all the teeth: before any interference into enamel, polishing with orthodontic paste, etching and application of a bonding system, orthodontic bracket bonding, orthodontic bracket removal, cleaning off adhesive residue. He proposed a dedicated method for the analysis and processing of images involving median filtering, mathematical morphology, binarization, polynomial approximation and the active contour method. The obtained results enabled him to automatically measure tooth enamel thickness in 5 seconds. They finally concluded that this method has proven to be an effective diagnostic tool that allows evaluation of the surface and cross section of tooth enamel after orthodontic treatment.

Suliman et al⁶ (2015) did a quantitative analysis using a three-dimensional optical scanner in vitro to measure enamel surface changes after debonding and clean of polycrystalline and monocrystalline ceramic brackets. Forty extracted teeth were scanned (baseline). Seven days later, brackets were debonded and scanned (post-debond). Adhesive remnants and bracket fragments were recorded. Tooth surfaces were cleaned using a finishing carbide bur and scanned again (post-cleanup). Post-debond and post-cleanup scans were aligned with the baseline, and surface changes were quantified. The study showed that polycrystalline ceramic brackets had slightly more enamel loss post-cleanup, which was attributed to the debonding process that left more resin and bracket fragments on the teeth and resulted in a more demanding cleanup. The final enamel loss after clean up with a multi-fluted carbide bur was 20–30 µm for either ceramic bracket system.

Olszowska et al⁵⁷ (2015) did a study using 3D analysis of adhesive remnants and enamel loss following the debonding of orthodontic molar tubes and orthodontic clean up to assess the effectiveness and safety of one-Step Finisher and Polisher and adhesive residue remover in comparison to tungsten carbide bur. Direct 3D scanning in blue-light technology to the nearest 2 µm was performed before etching and after adhesive removal. Adhesive remnant height and volume as well as enamel loss depth and volume were calculated. The study concluded that the evaluated tools were all characterized by similar effectiveness with regards to enamel.

Armamentarium

COLLECTION OF NATURAL TEETH

1. Normal saline
2. 2% Thymol solution
3. Disposable gloves
4. Vented glass bottles
5. Tissue forceps

Preparation and selection of samples (basic armamentarium)

1. Magnifying Lens with Illumination
2. Magnifying loupe
3. Modeling wax
4. PVC Plastic pipes(1.5inch diameter)
5. Type III dental stone
6. Rubber bowl and spatula
7. N 95 masks
8. Marking pen
9. Labelled storage boxes
10. Illumination light
11. Goggles and Gloves

Armamentarium for bonding and debonding

1. Metal brackets (Mini Master series-American orthodontics)
2. Ceramic brackets (Radiance-American orthodontics)
3. Bracket holder (Skodi orthodontics)
4. Transbond XT Primer(3M UNITEK)(Figure: 10)
5. Transbond XT adhesive(3M UNITEK) (Figure: 10)
6. Transbond XT Self etch primer(3M UNITEK) (Figure: 11)
7. N-etch 37% Orthophosphoric acid(IVOCLAR) (Figure: 10)
8. Light curing unit (IVOCLAR VIVADENT-BLUEPHASE-N MC) (Figure: 5)
9. Conventional debonding plier(Skodi orthodontics)(Figure: 6)
10. High speed tungsten carbide finishing bur(SS WHITE –FG-7642) (Figure: 7)
11. Low speed tungsten carbide finishing bur(SS WHITE–RA-703SL) (Figure: 7)
12. Airotor hand piece(NSK) (Figure: 8)
13. Contra angled micromotor hand piece(NSK)(Figure: 8)

Preparation for Optical coherence tomography scanning

Wooden jig of 10cm*3.5cm with a circular hole in the centre with a diameter of 1.5inch to accommodate the mounted samples. (Figure: 3)

Image analysis

1. Rt vue OCT Software
2. In built computer along with the OCT machine with windows XP operating system. (Figure: 1&2)

ARMAMENTARIUM

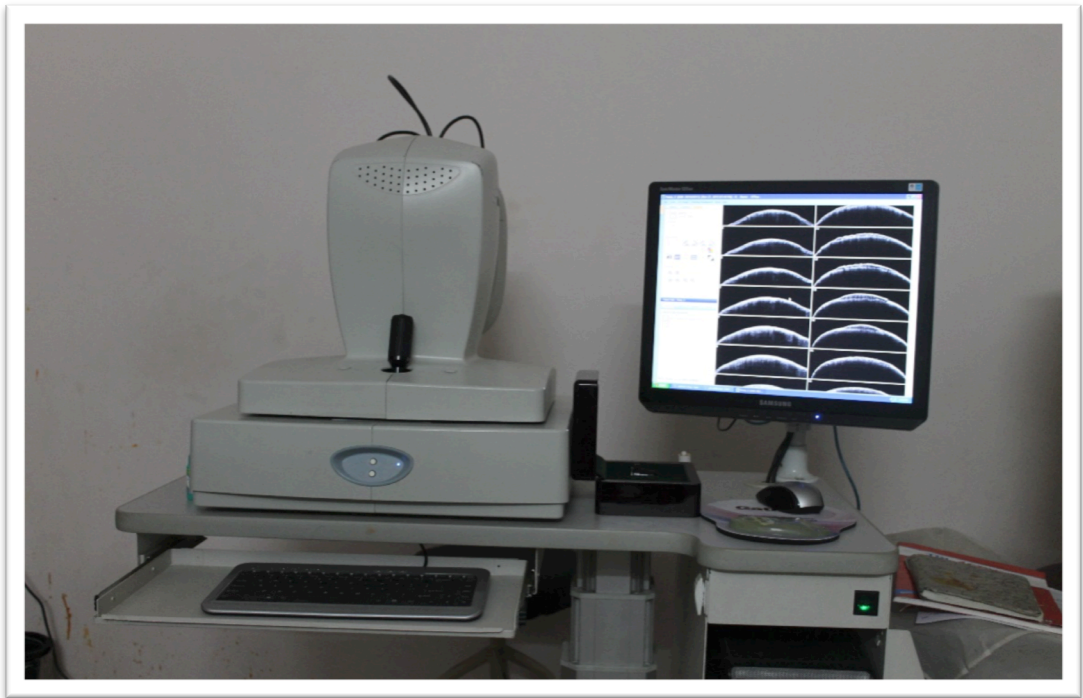


Figure 1: Optical coherence tomography unit



Figure 2: Tooth sample in OCT unit



Figure 3: Custom made wooden jig

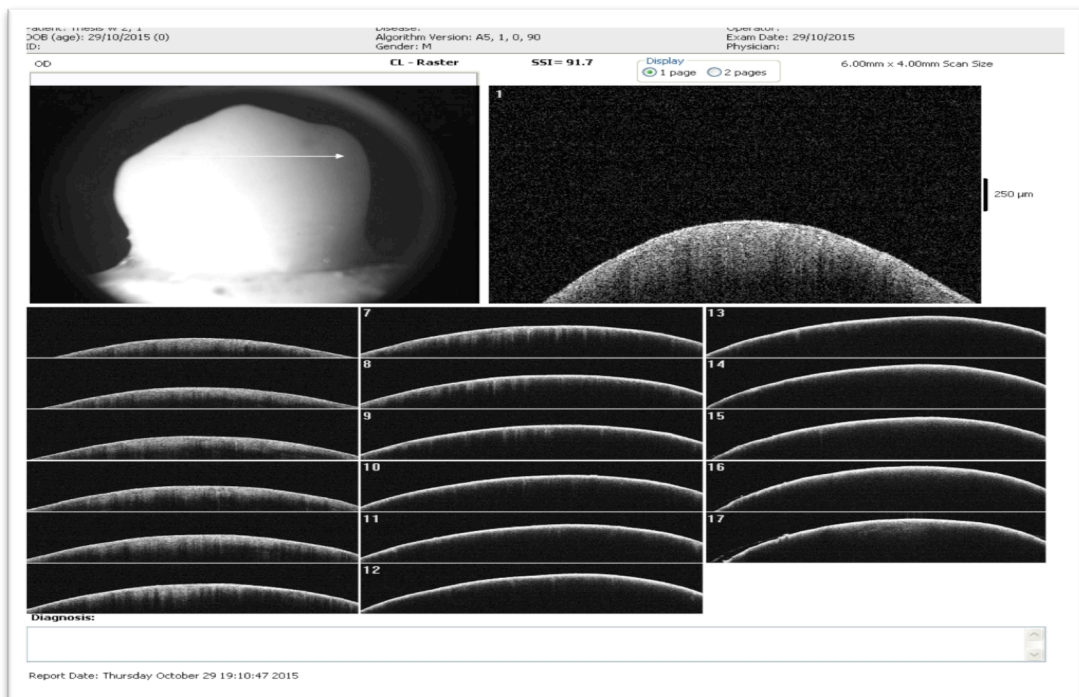


Figure 4: Base line OCT scan



Figure 5: Light Curing unit

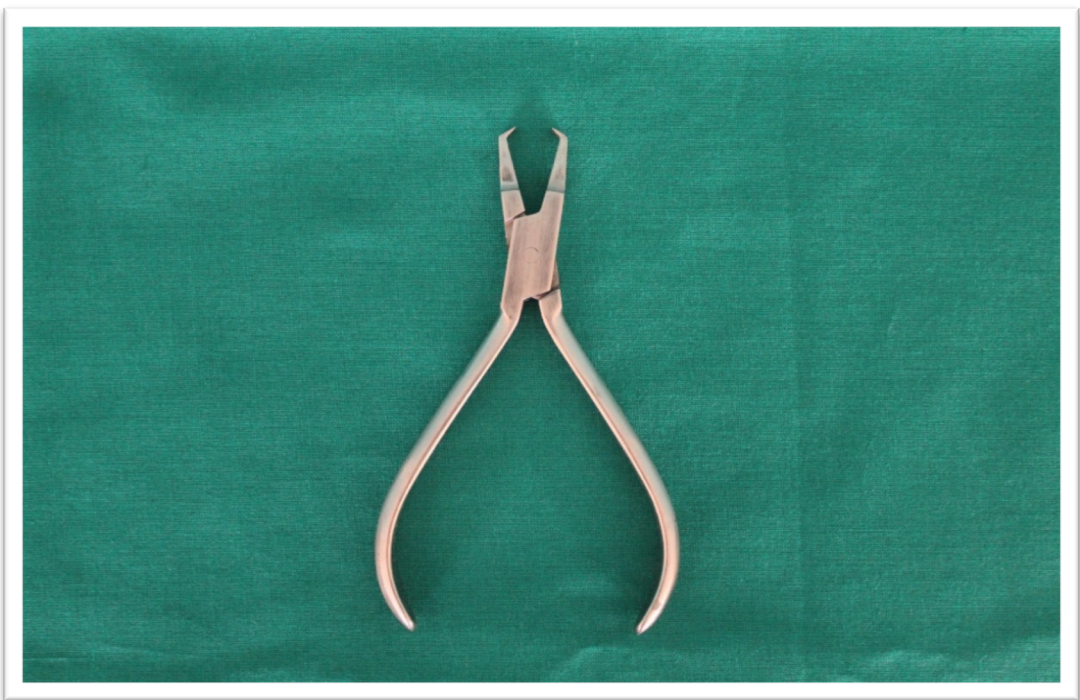


Figure 6: Bracket removing plier



Figure 7: Low and high speed tungsten carbide burs



Figure 8: Contra angled Airotor and Micromotor Hand piec

1. Collection of teeth:

A total of freshly extracted 250 human premolars were collected and stored in a solution of 2% Thymol for 15 days.

2. Selection of samples:**Inclusion criteria:**

1. Anatomically and morphologically well-defined teeth
2. Intact buccal enamel, extracted for orthodontic purpose only

Exclusion criteria:

- Teeth with restorations
- Variations in crown morphology with enamel structural defect
- Teeth having surface cracks from extraction forceps
- Teeth treated with chemical agents
- Fluorosed teeth.

All the samples after inspection by illumination and magnification following these criteria underwent an OCT scan to rule out samples that had cracks and subsurface demineralization.

3. Sample size:

A total of one hundred and sixty teeth were selected for the purpose of the study.

4. Preparation of the sample :

The teeth were cleansed and then polished with pumice and rubber prophylactic cups for 10 seconds.

5. Mounting of samples:

The prepared samples were mounted on a PVC pipe with a 1.5inch diameter and 4cm in length using Type III dental stone. The same procedure was repeated for all the one hundred and sixty samples.

6. Bonding procedure :

A total of 160 brackets are used in this study

Group A: 80 Metal brackets (**Mini master series**-American orthodontics)

Group B: 80 ceramic brackets (**Radiance** –American orthodontics)

These two groups were further divided into two Sub groups based on the type of bonding system used and bonded on the buccal surface of the premolars according to the manufacturer's guidelines.

a) Conventional etch adhesive system

1. The area where the bracket was to be located was etched with a 37% orthophosphoric acid gel (N-etch, IVOCLAR) for 15 seconds and then washed with water.
2. After washing, the enamel surface was completely dried with compressed oil-free air.
3. A thin coating of Transbond XT primer (3MUnitek) was painted on the surface and lightly air dried.
4. The mesh pad of stainless steel, standard premolar brackets (American Orthodontics) were coated with a single coating of Transbond XT adhesive (3M Unitek).
5. The brackets were placed in the middle of the tooth in occlusal gingival and mesial distal directions, and seated with firm pressure.

6. Excess adhesive resin was carefully removed with an explorer.
7. The bracket was cured with an BLUEPHASE NMC LED curing light (IVOCLAR VIVADENT) for 5 seconds mesially, 5 seconds distally, 5 seconds occlusally, and 5 seconds gingivally for a total of 20 seconds.

b) Self etch adhesive system

1. Transbond Plus SEP was gently rubbed onto the surface for approximately three seconds with the disposable applicator supplied with the system.
2. Then, a moisture-free air source was used to deliver a gentle burst of air to the enamel and cured for 15 seconds.
3. The brackets were placed in the middle of the tooth in occlusal gingival and mesial distal directions, and seated with firm pressure.
4. Excess adhesive resin was carefully removed with an explorer.
5. The bracket was cured with an BLUEPHASE NMC LED curing light (IVOCLAR VIVADENT) for 5 seconds mesially, 5 seconds distally, 5 seconds occlusally, and 5 seconds gingivally for a total of 20 seconds.

GROUPING DESIGN FOR BONDING (Figure: 19)

Group A-Metal brackets (A1&A2)

1. 40 metal brackets using conventional etch adhesive system
2. 40 metal brackets using self etch adhesive system

Group B-Ceramic brackets (B1&B2)

1. 40 ceramic brackets using conventional etch adhesive system
2. 40 ceramic brackets using self etch adhesive system

7. Debonding procedure

All teeth were debonded following the same protocol. A bracket-removing plier was placed against the wings of the bracket and squeezed. Squeezing the bracket wings causes distortion of the bracket pad and induces bond failure between the pad and the adhesive resin. This method has been described as the safest way to cause least damage to the enamel (Knosel et al 2010)⁵¹.

8. Enamel surface evaluation using optical coherence tomography after debonding

After debonding, OCT Images were taken for all the 160 samples using the RTVue (Optovue) OCT unit which provides a software programme to automatically assesses the changes in the enamel surface.

Images required for the study are processed by using the Rtvue scanner (Optovue) with resolution depth of 5.0 μm , scan depth of 2 - 2.3mm and scan beam wavelength of $\lambda=840 \pm 10\text{nm}$. The scanning camera work with a working distance from the object of imaging of 22mm and with a motorized focus range of -15D to +20D. The scanner is connected to the preconfigured PC, which works on a windows XP operating system with the following configuration (CPU: 2.66 GHz Quad-Core Processor, RAM 4GB and 1 TB hard disk).

Two types of images were visualized in this study

1. En face image (Figure: 21)
2. Two dimensional (2D) cross sectional optical tomographic image (Figure: 21).

Image processing was done by two methods**a) Line scanning**

A line scan constructs a 2D cross sectional image at a particular point selected over the tooth surface using the en face image, which is denoted by a arrow mark passing mesiodistally.

b) Raster scanning

This method uses random software generated 2D line scans, which entails the region of interest (ROI) of the sample. It produces line scans at a distance of 5 μ m distance between each line scan. The numbers for numerous line scans are provided by the software and are ordered occlusogingivally. The arrow mark passing mesiodistally in the en face image corresponds to each line scans in order from number 1 till the maximum number of 2D scans that the scanner had taken.

In this study, Raster scanning was done for all the samples to obtain numerous cross sectional 2D images.

Three cross sectional 2D images (zones) were selected for measurement from the numerous line scans given by the raster scanning method. The three zones were standardized for all the samples with each zone corresponding to occlusal one third, middle one third and gingival one third of the bracket base area viewed with the help of the en face image and the arrow mark passing mesiodistally (Zone 1,Zone 2,Zone 3: occlusal, mid, gingival)(Figure: 22,23,24).

Quantification of the remaining adhesive

Two parameters were quantified from these images

1. Remaining adhesive layer in depth
2. Remaining adhesive layer in area

Remaining adhesive layer in depth was measured using the digital caliper scale provided in the software at three points, which is standardized using the measuring tool in the software program at all the three zones.

The three points were marked corresponding to the mesial, mid and distal slopes of the tooth surface.

Total of nine values were obtained for the depth in μm for each sample and their mean were calculated and the values were statistically analyzed (Table: 1, Chart: 1).

Remaining adhesive layer in area was measured using the area-measuring tool provided in the software in all the same three zones.

Total of three values from three zones were obtained for area in mm^2 for each sample and their mean were tabulated and the values were statistically analyzed. (Table: I, Chart: I).

7. Clean up procedure

All the 40 samples from each sub group was further divided into two groups based on two clean up procedures

- a) High speed tungsten carbide bur
- b) Low speed tungsten carbide bur

Grouping design illustration (Figure: 19)

Group A1 (A1a&A1b)

- a) High speed tungsten carbide bur
- b) Low speed tungsten carbide bur

Similarly all other groups were categorized

The cleanup was performed by a single operator, with the bur positioned parallel to the long axis of the teeth and horizontal movements. The procedure was considered complete after visual and macroscopic observation using magnification loupe for satisfactory removal of the remnants.

After cleanup, OCT Images were again taken for all the 160 samples.

Two types of scanning methods were used post clean up

- a) Pachymetry scanning to assess the degree of enamel loss.
- b) Raster scanning to quantify the layer of adhesive remnant in depth and area post clean up.

a) Pachymetry scanning

In Pachymetry scanning, enamel thickness was measured normal to the anterior surface and presented as color pachymetry maps and zonal statistics. A thickness profile was generated from each meridional cross section and the computer algorithm registered the 8 cross sections and computed the enamel thickness (pachymetry) map. The pachymetry map was presented on a banded color scale. The map was divided into a central zone (<2 mm) and 3 annular zones by diameter: pericentral, 2 to 5 mm; transitional, 5 to 7 mm; and peripheral, >7 mm. The mean, maximum, and minimum pachymetries within the central, pericentral, and transitional sectors respectively were computed (Figure: 25).

In the present study pachymetry analysis was done to analyse the changes in the thickness profile of enamel surface at eight cross sections using the mean value obtained in the central sector of the pachymetry map.

To determine and assess the method, the ranges of enamel thickness obtained by the scanner were categorized and comparison was made between the preliminary scan and post clean up scan to determine whether there is a significant difference in the ranges of enamel thickness (Figure: 26,27).

Base line and post clean up Pachymetry mean values were taken using the software and the loss of enamel thickness in range was categorised and statistically analysed (Table: III, Chart: III).

b) Raster scanning and quantification of remaning adhesive layer in area and depth post clean up

Remaining adhesive layer in depth was measured using the digital caliper scale provided in the software at the maximum depth of adhesive penetration at all the three zones (Figure: 28,29).

Total of three values were obtained for the depth in μm for each sample and their mean were calculated and the values were statistically analyzed (Table: IV, Chart: IV).

Remaining adhesive layer in area was also measured using the area-measuring tool provided in the software in all the same three zones (Figure: 28,29).

Total of three values were obtained for area in mm^2 for each sample and their mean were tabulated and the values were statistically analyzed (Table: IV, Chart: IV).

MATERIALS AND METHODS



Figure 9: Tooth samples



Figure 10: Conventional etch adhesive system

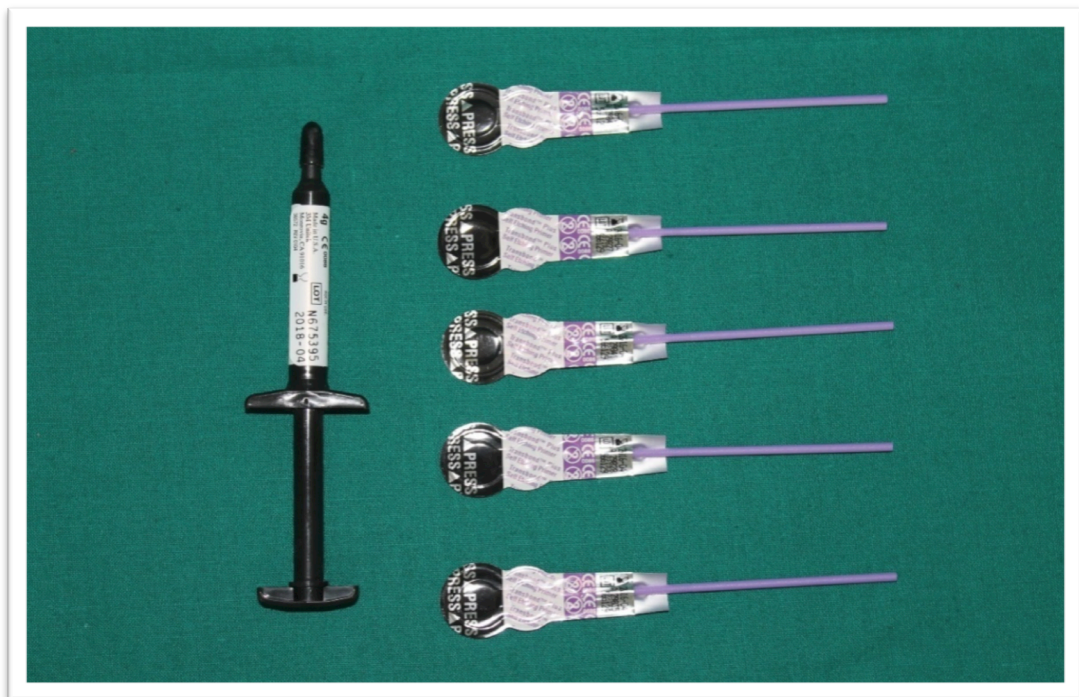


Figure 11: Self etch adhesive system



Figure 12: Application of 37% orthophosphoric acid



Figure 13: Application of self etch primer

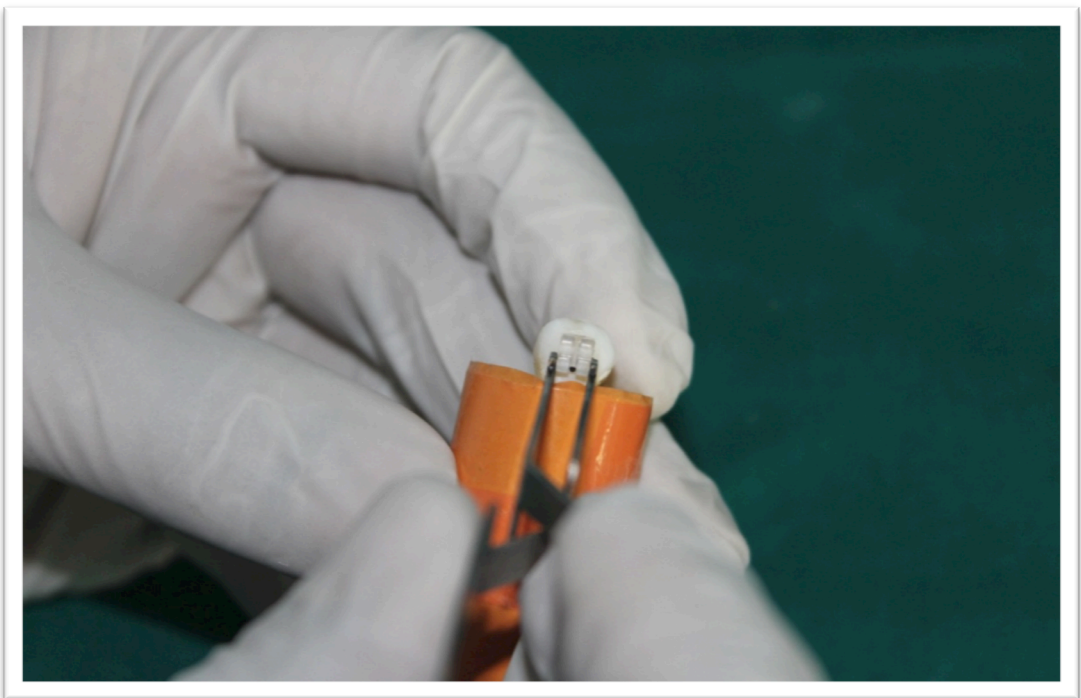


Figure 14: Bracket positioning



Figure 15: Light Curing

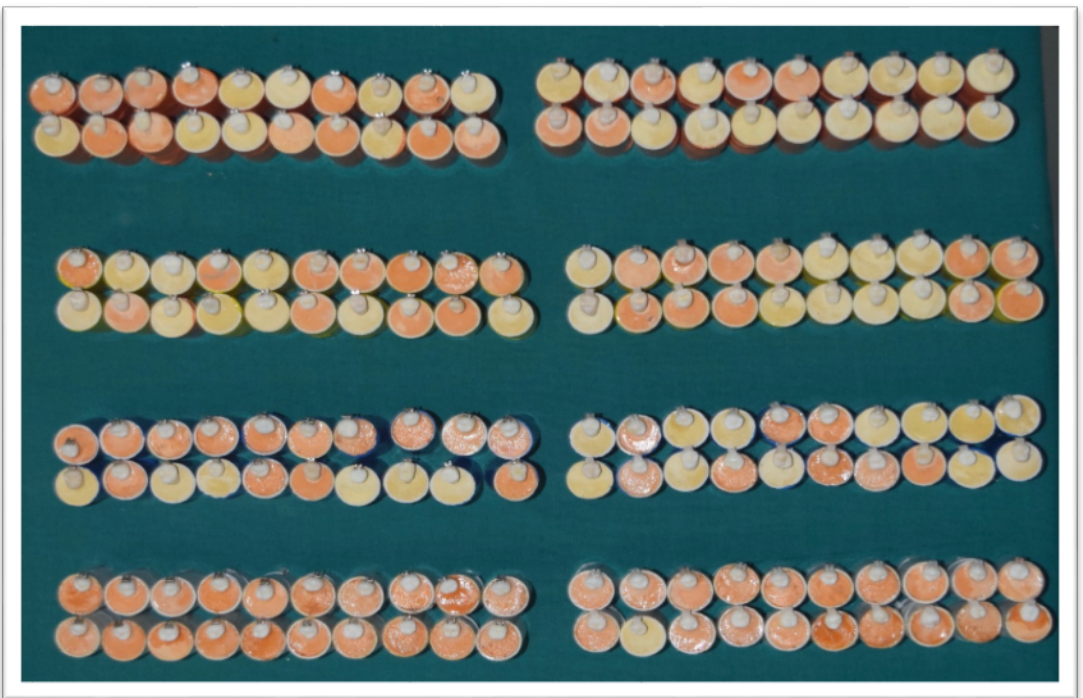


Figure 16: Bonded tooth samples



Figure 17: Bracket debonding

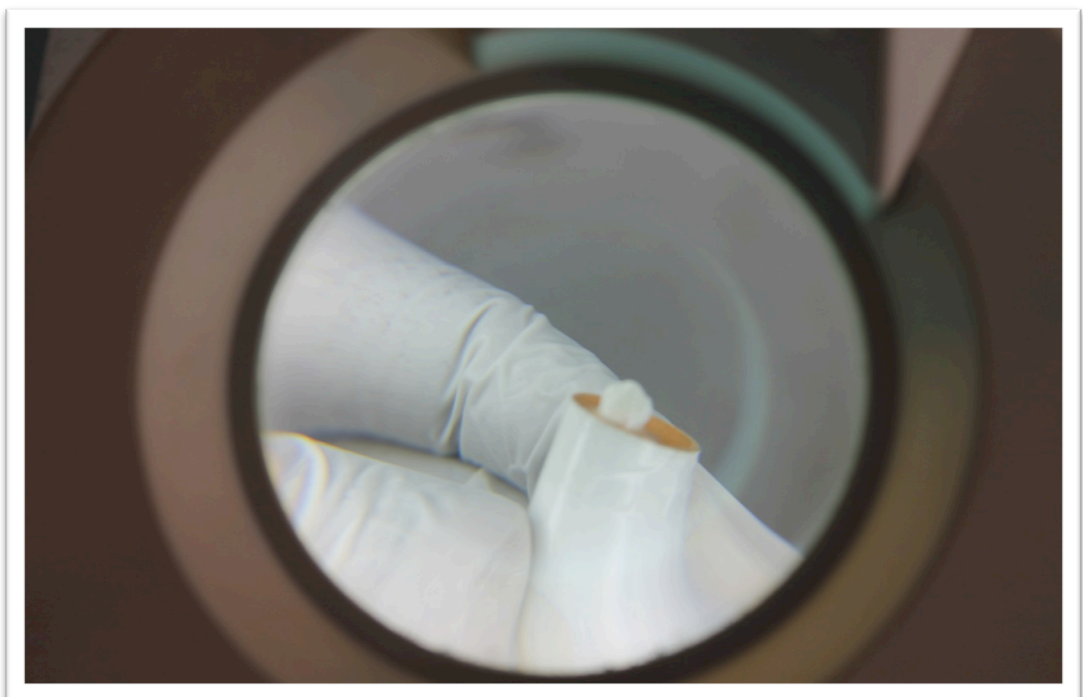
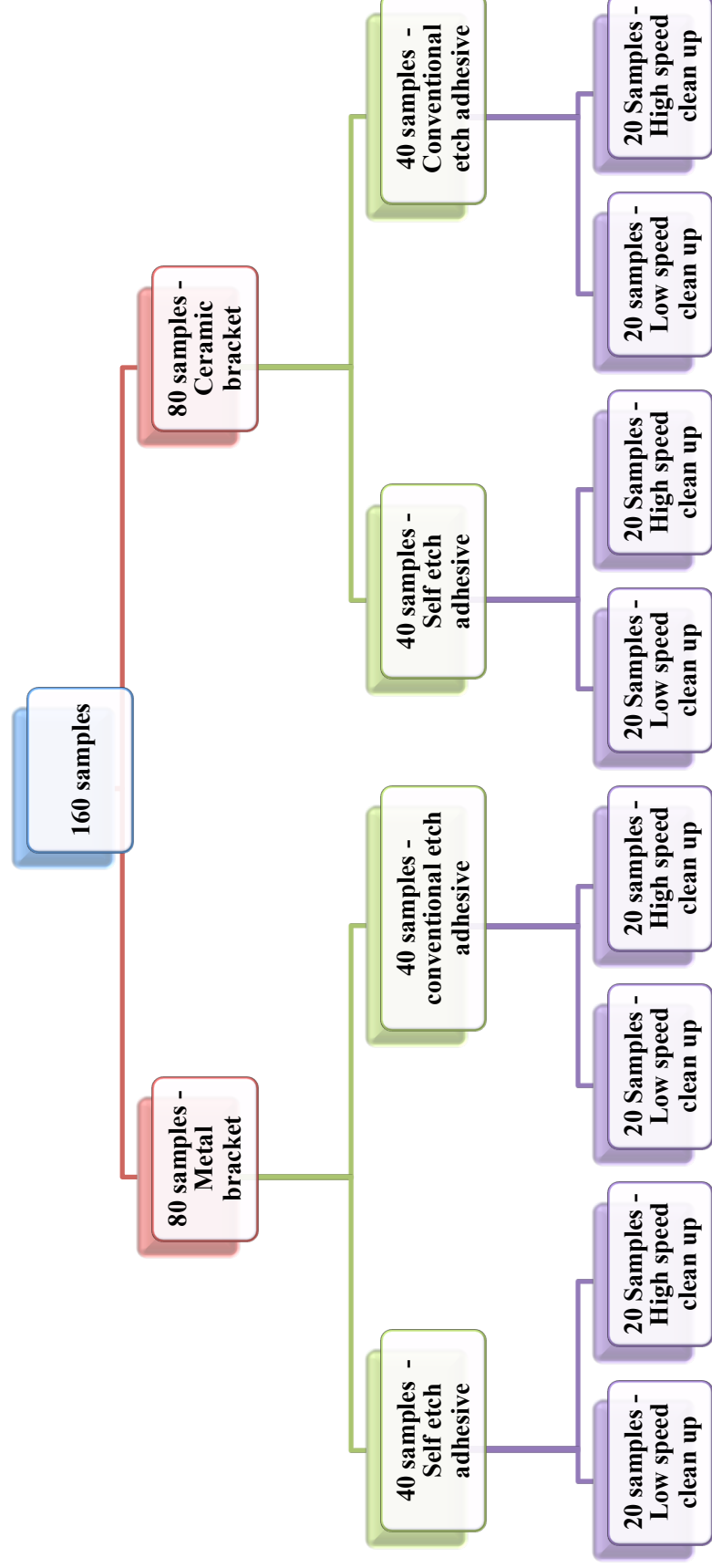


Figure 18: Examination under magnifying loupe

SAMPLE DISTRIBUTION (Figure 19)



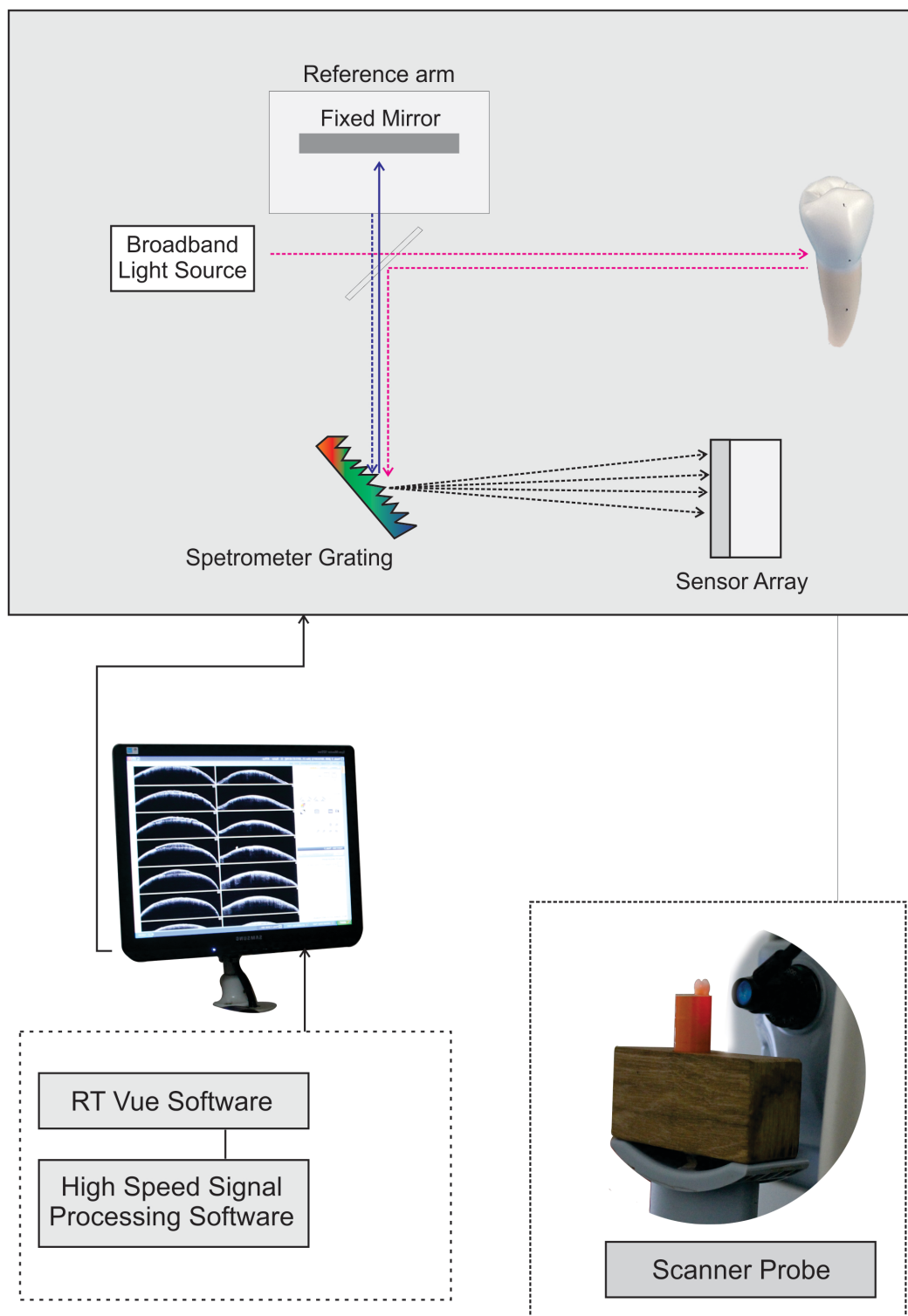
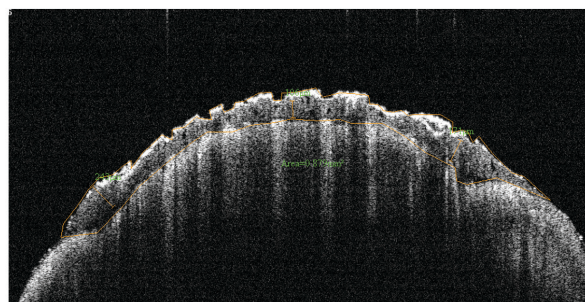
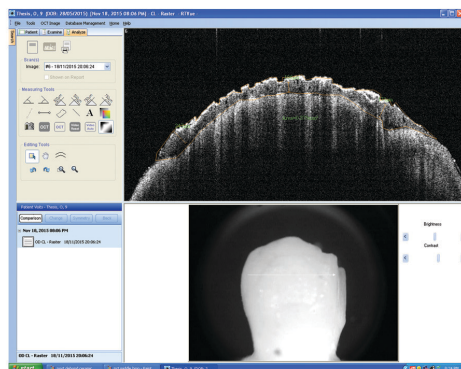
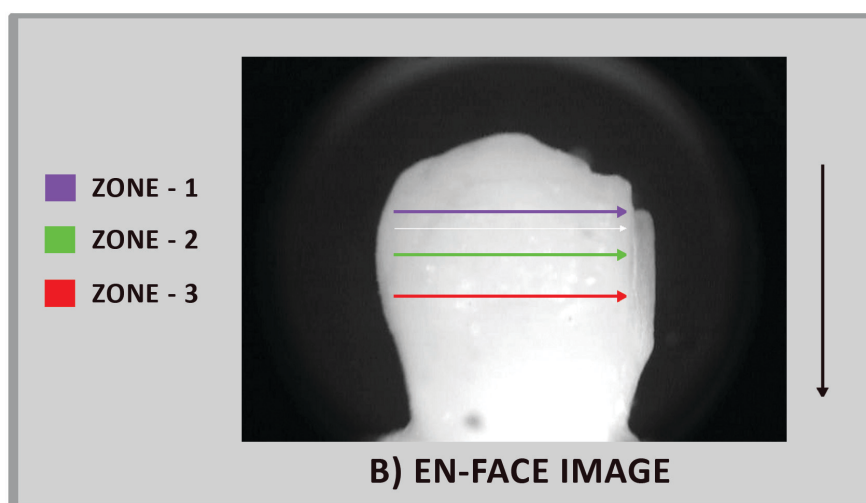


Figure: 20 Schematic representation of spectral / Fourier Optical Coherence Tomography.



B) AXIAL 2D IMAGE



B) EN-FACE IMAGE

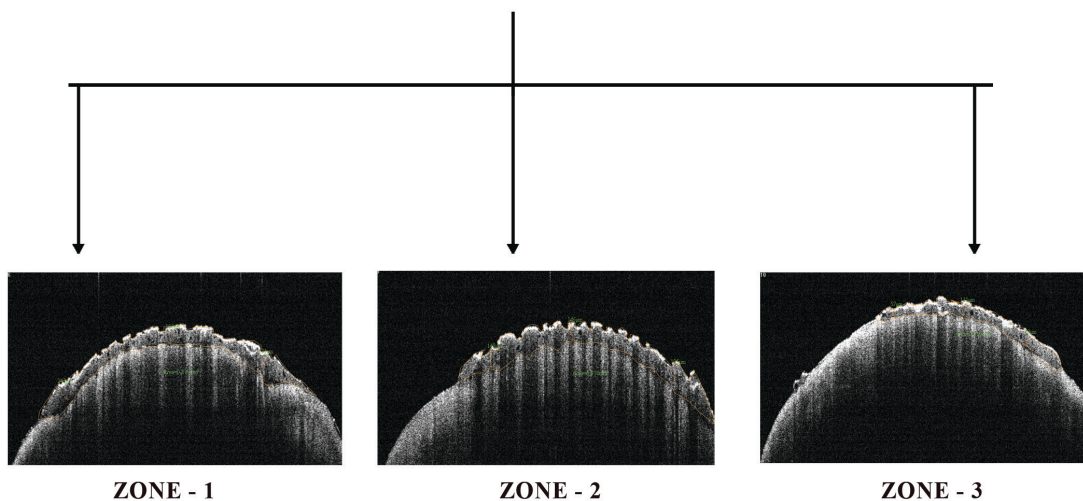


Figure: 21 Schematic representation of a) Axial cross sectional 2D image b) Enface Image using Optical Coherence Tomography.

Table I: Comparison of remaining adhesive layer in area (RALA) and depth (RALD) of metal and ceramic brackets under two adhesive systems post debonding.

Groups	Post Debond RALD (μm)		Post Debond RALA (mm^2)	
	Ceramic	Metallic	Ceramic	Metallic
Self etch adhesive system	157.24 \pm 21.54	155.38 \pm 16.89	1.222 \pm 0.07	0.828 \pm 0.04
t value	0.430		22.327**	
Conventional etch adhesive system	160.63 \pm 29.67	160.14 \pm 26.62	0.967 \pm 0.04	0.65 \pm 0.07
t value	0.077		25.585**	

* - significant at 0.05 level

** - significant at 0.01 level

Statistical analysis:

To identify differences in mean depth and area of remaining adhesive of two main groups under two sub groups student's t test was performed.

Result:

This table summarizes the results indicating that there is significant differences in the residual adhesive layer in area between metal brackets and ceramic brackets and there is no significant differences in residual adhesive layer in depth between metal and ceramic brackets under conventional etch adhesive system and self etch adhesive system respectively.

Chart I: Distribution of remaining adhesive layer in depth and area post debonding between metal and ceramic brackets under conventional etch adhesive system and self etch adhesive system

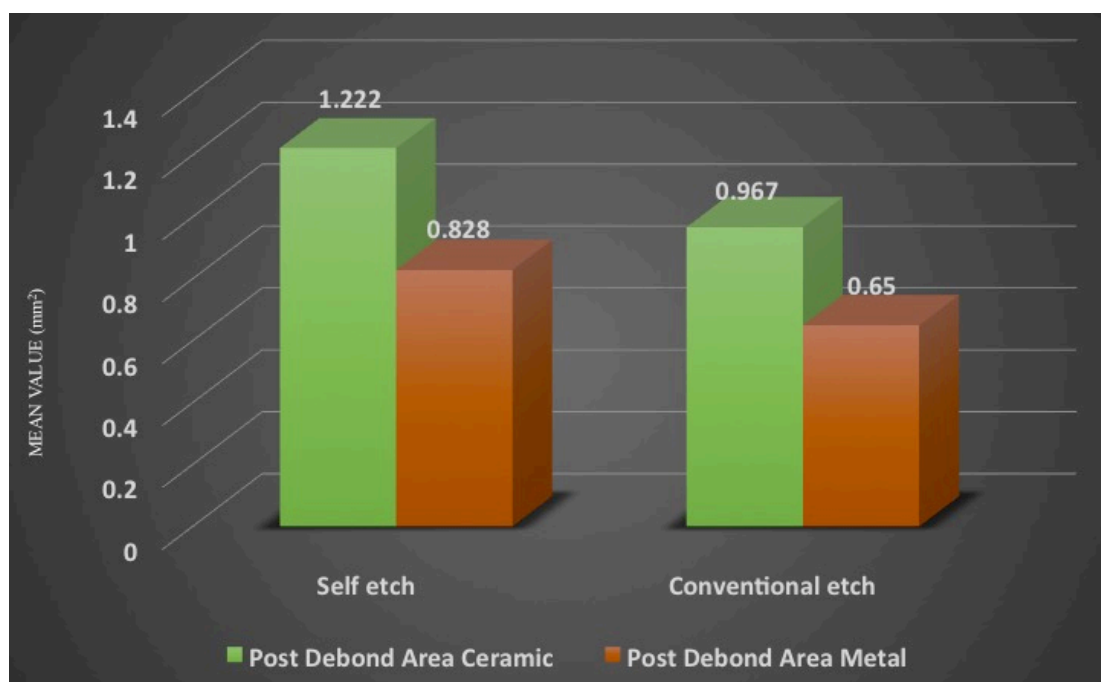
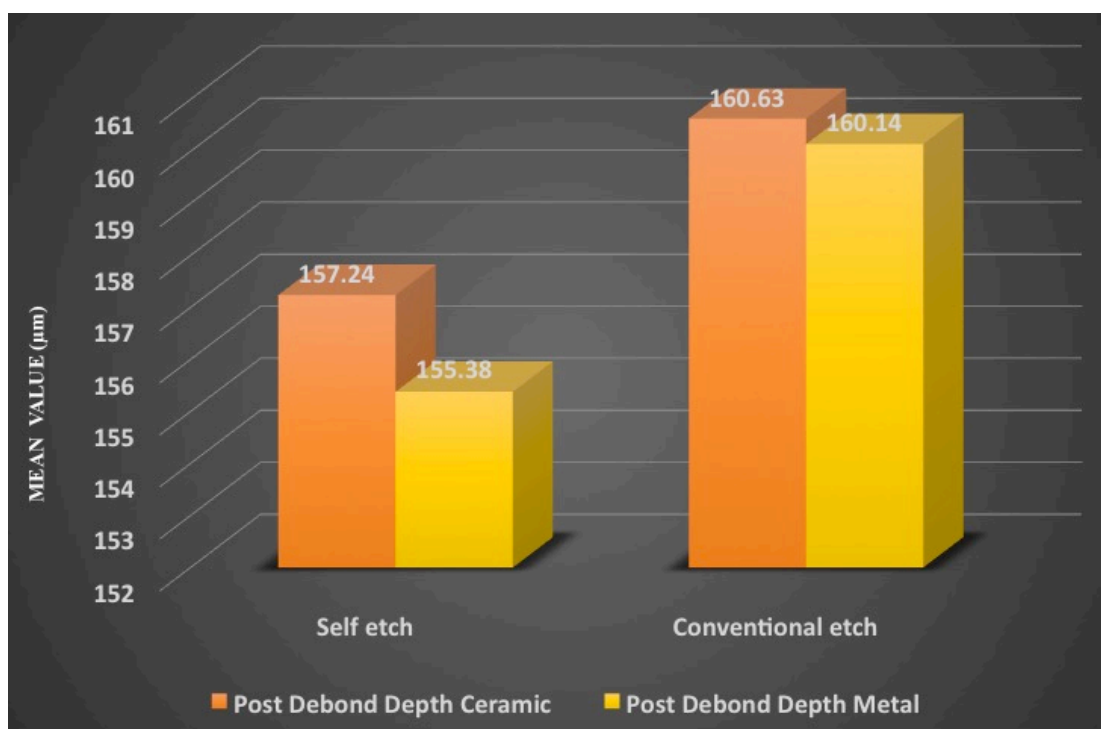


Figure 22: Measurement of remaining adhesive layer in area and depth post debonding in three zones.

ZONE 1

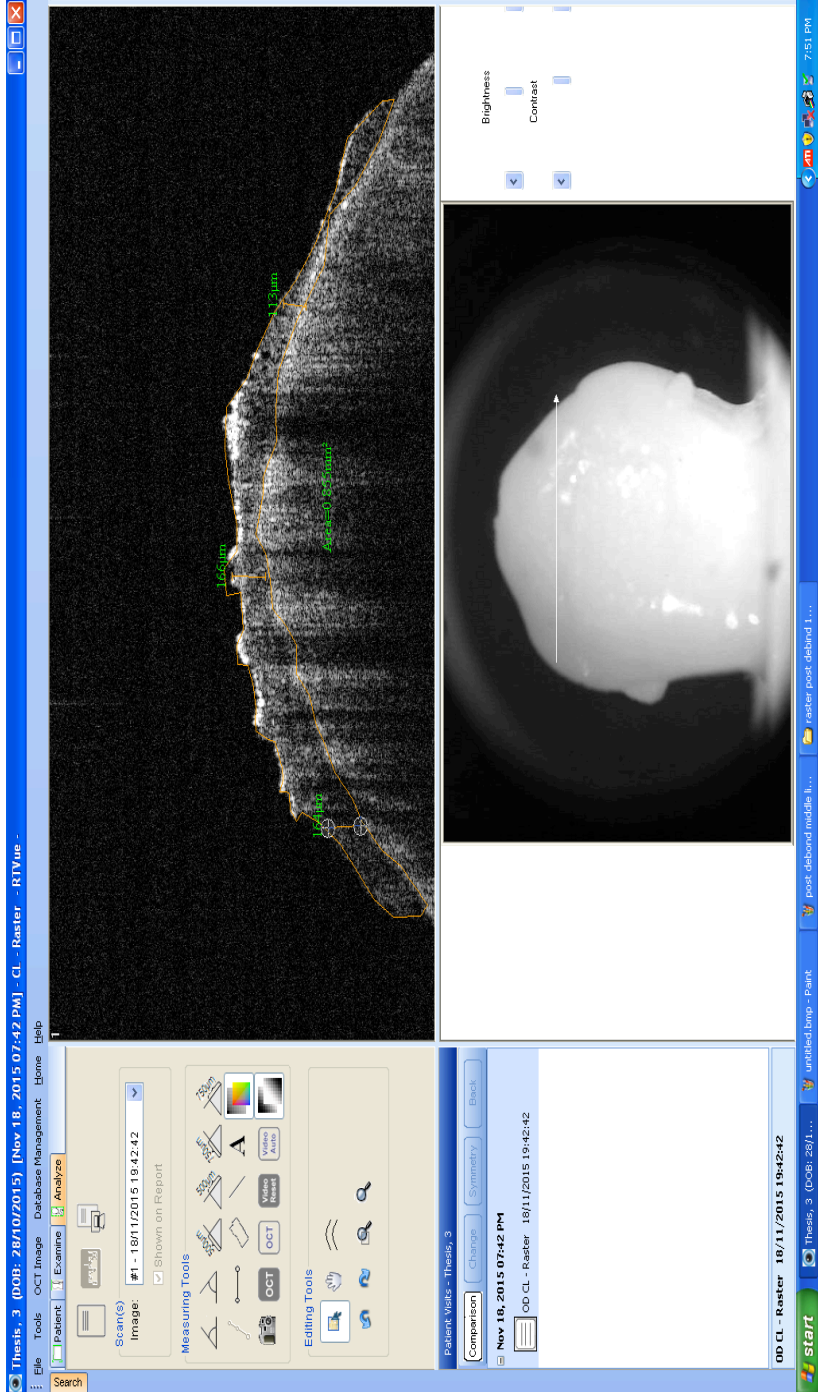


Figure 23 : Measurement of remaining adhesive layer in area and depth post debonding

ZONE 2

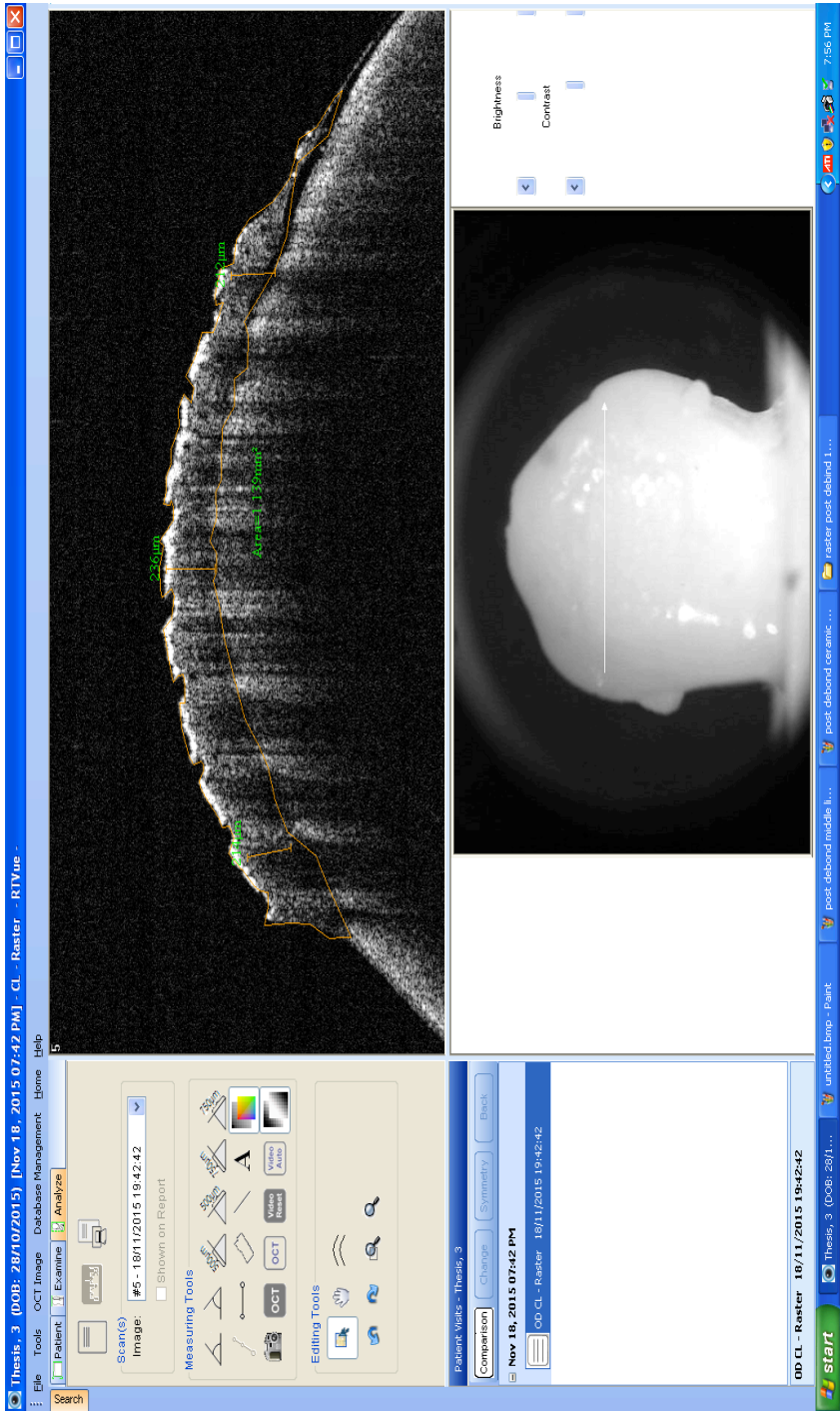
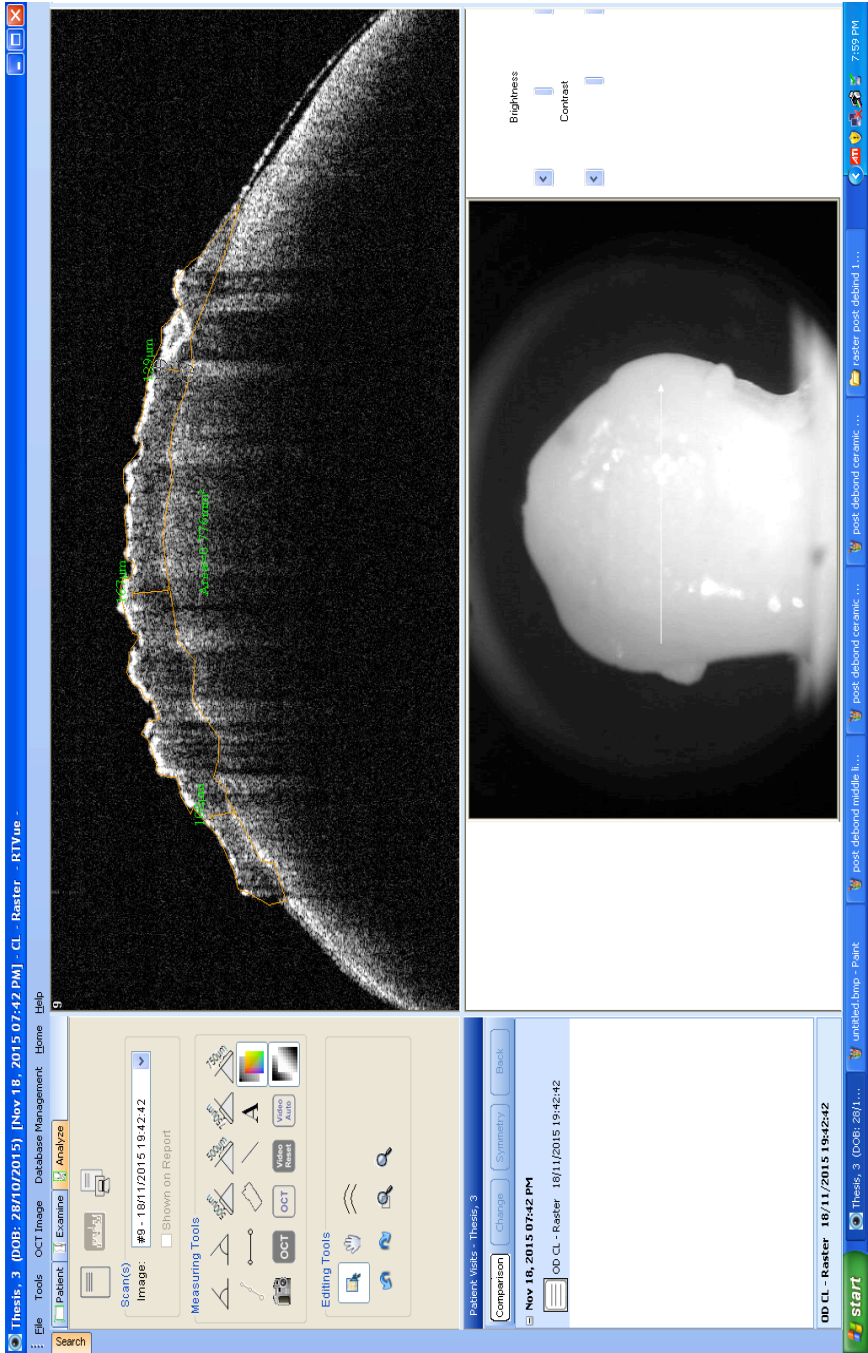


Figure 24 : Measurement of remaining adhesive layer in area and depth post debonding

ZONE 3



The enamel thickness in ranges was measured using pachymetry scanning before and after the clean up process and the data was classified into five groups of equal distribution.

The data below represents the distribution of 160 samples across the enamel thickness range that was measured by the device from the surface of the enamel.

Table II: Distribution of enamel thickness in ranges between baseline and post clean up scan

Enamel thickness in range μm	Baseline	Clean up
600-640	2	43
641-680	24	47
681-720	42	46
721-760	47	19
761-800	45	5
Total	160	160
Chi-square value	80.824**	

* - significant at 0.05 level

** - significant at 0.01 level

Statistical analysis:

The Chi-Square test was performed to evaluate whether there was a statistically significant difference between the two groups in terms of enamel loss in the above ranges.

Result:

There is a statistically significant difference in the enamel loss in ranges before and after the clean up procedure.

Chart II: Distribution of enamel thickness in ranges post clean up and their comparison with baseline scan irrespective of the type of clean up.

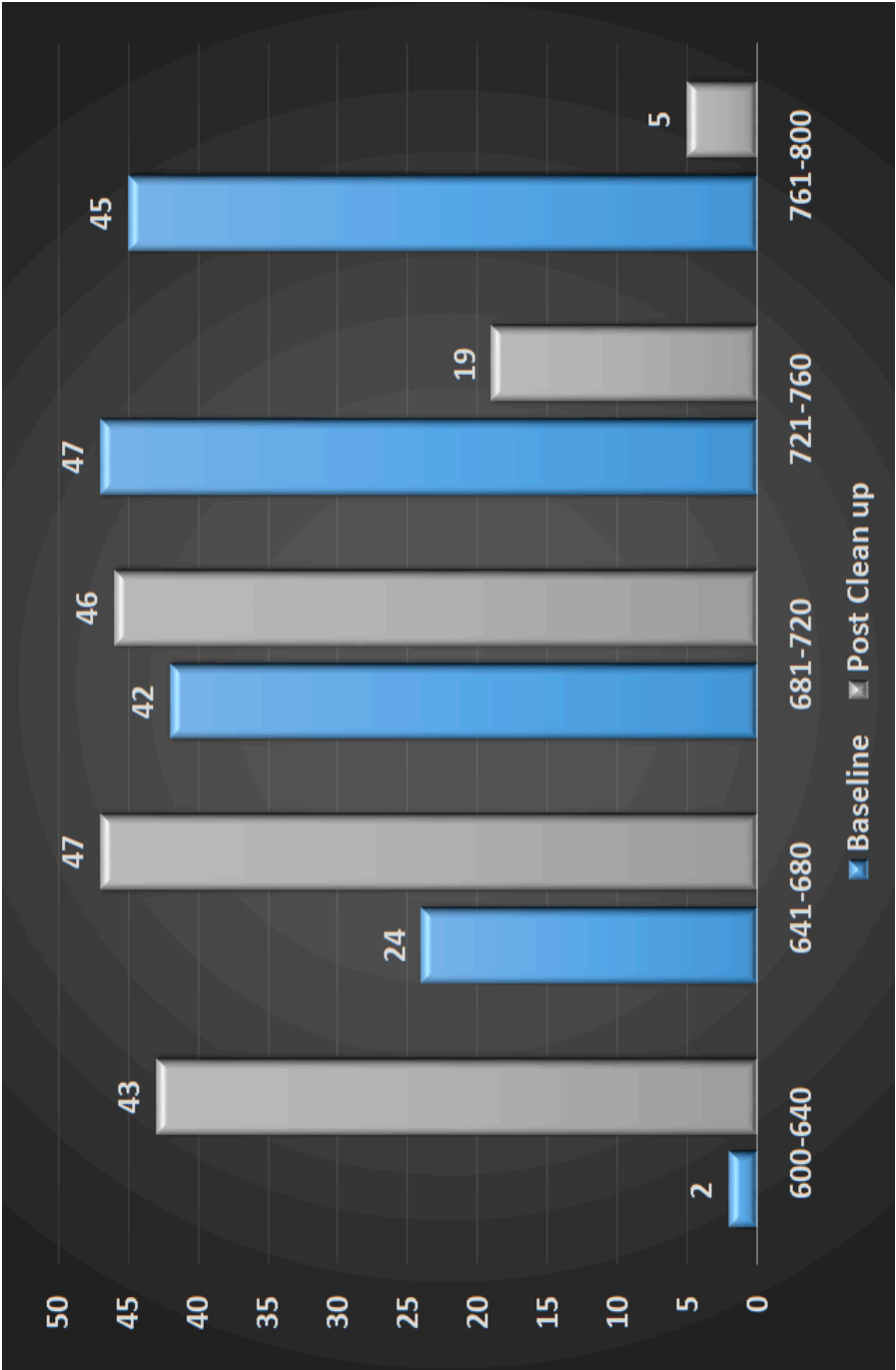


Table III: Distribution of enamel thickness range between baseline and post clean up for high speed and low speed clean up procedure

Enamel thickness in range (µm)	High speed		Low speed	
	Baseline	Post clean up	Baseline	Post clean up
600-640	1	38	1	5
641-680	11	26	13	21
681-720	16	12	26	34
721-760	23	3	24	16
761-800	29	1	16	4
Total	80	80	80	80
Chi-square	125.814**		72.778**	

* - Significant at 0.05 levels

** - Significant at 0.01 levels

Statistical analysis:

The Chi-Square test was performed to evaluate whether there was a statistically significant difference between the two groups in terms of enamel loss in the above ranges.

Result:

1. There is significant difference between the enamel loss in ranges before and after the high speed clean up procedure.
2. There is significant difference between the enamel loss in ranges before and after the low speed clean up procedure.

Chart III: Distribution of enamel thickness range between baseline and post clean up for high speed and low speed clean up procedure.

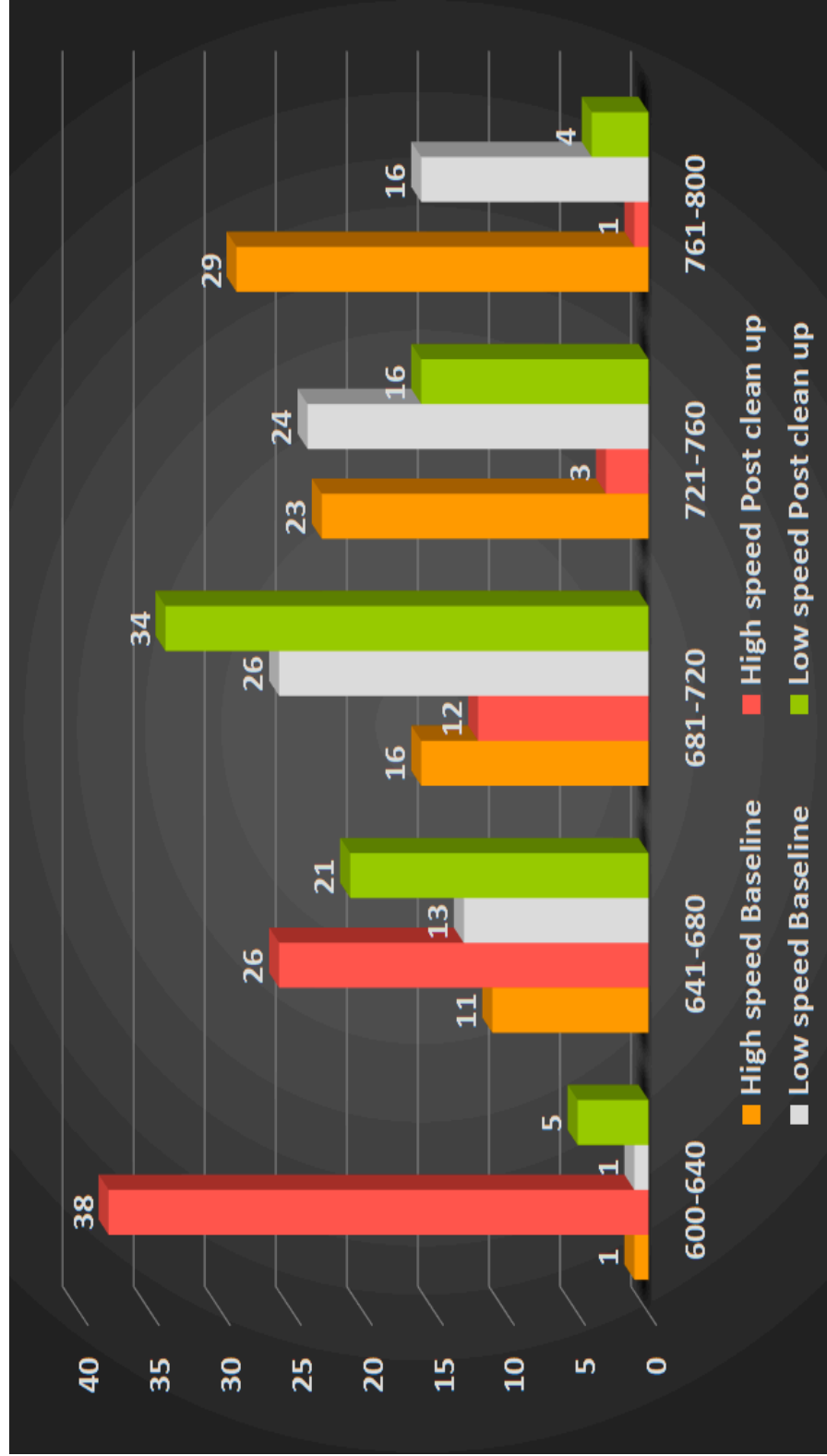


Figure 25: Measurement of enamel thickness range using pachymetry scanning

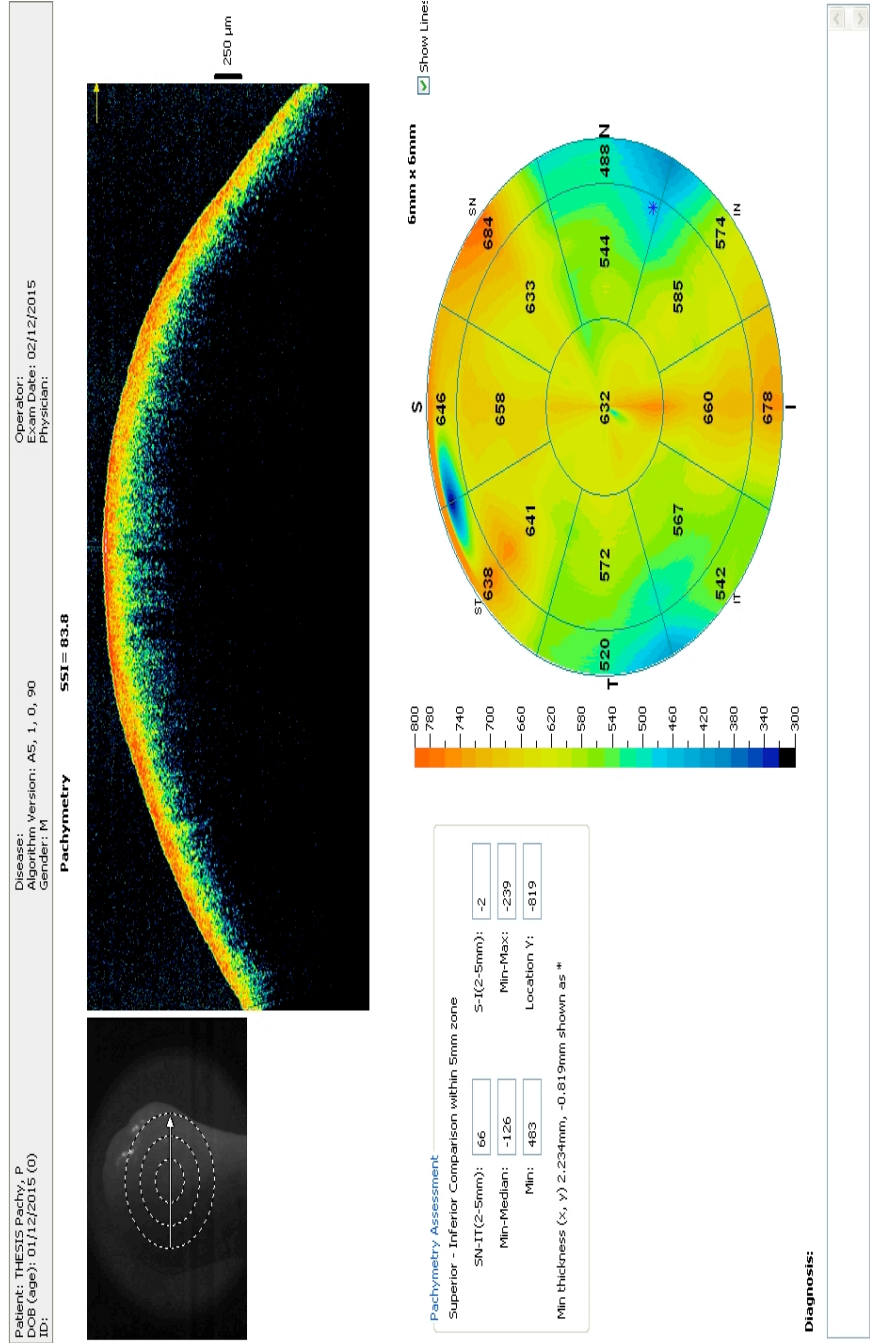


Figure 26: Comparison and analysis of baseline OCT scan with the post clean up scan while using low speed tungsten carbide bur

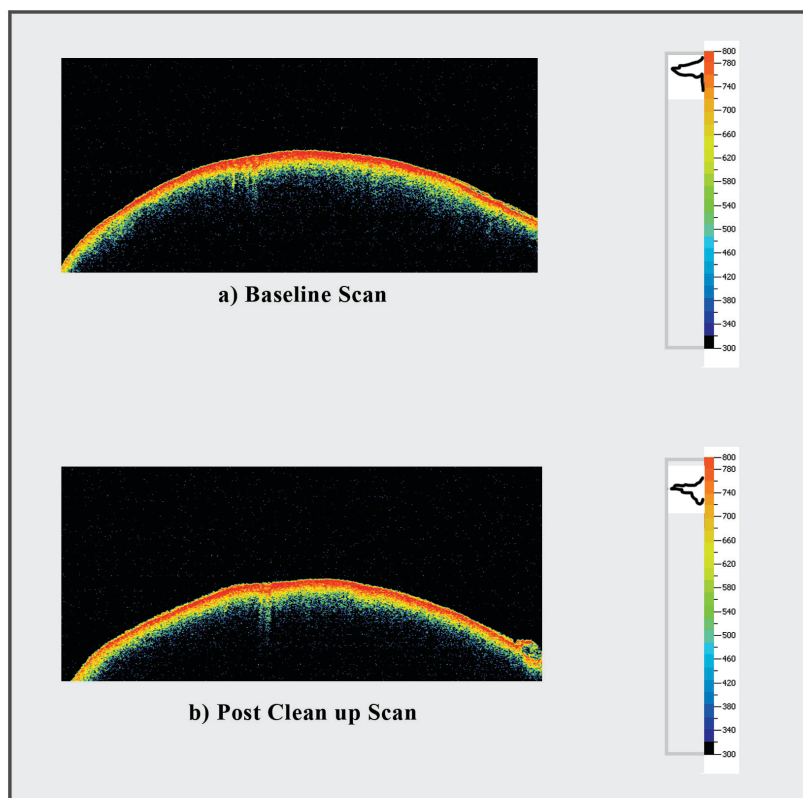
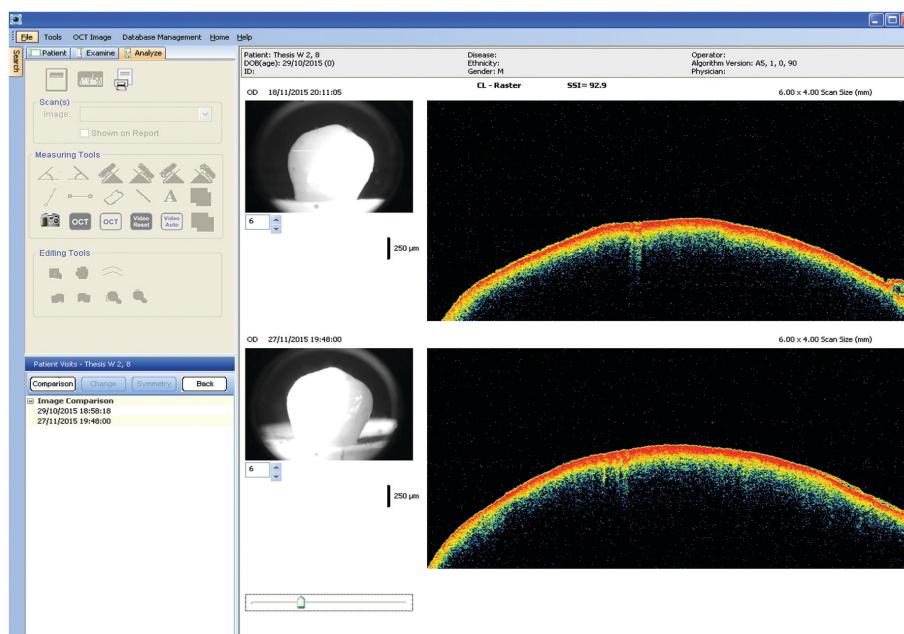


Figure 27: Comparison and analysis of baseline OCT scan with the post clean up scan while using high speed tungsten carbide bur

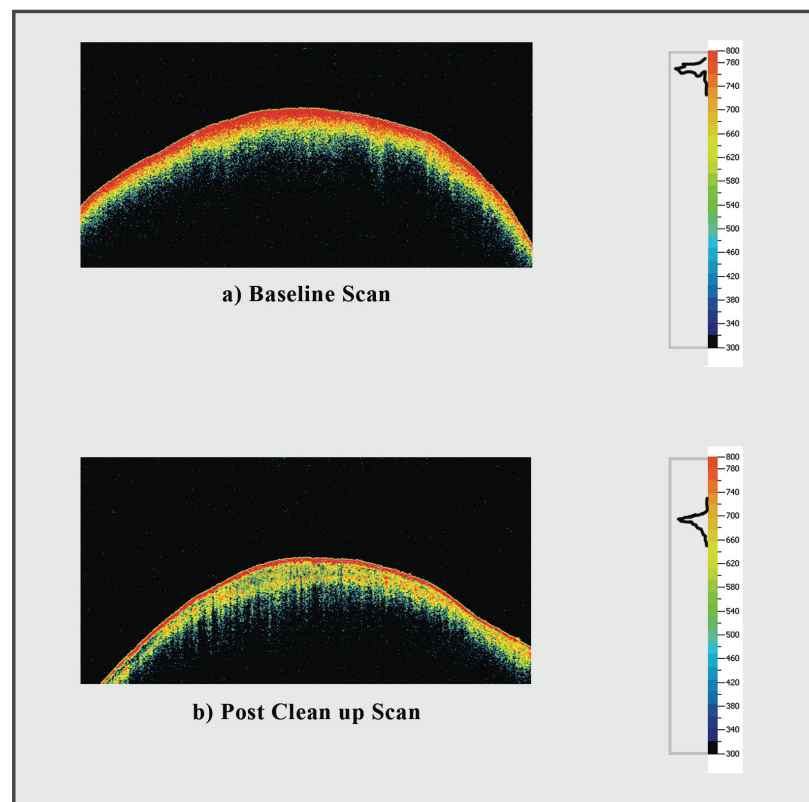
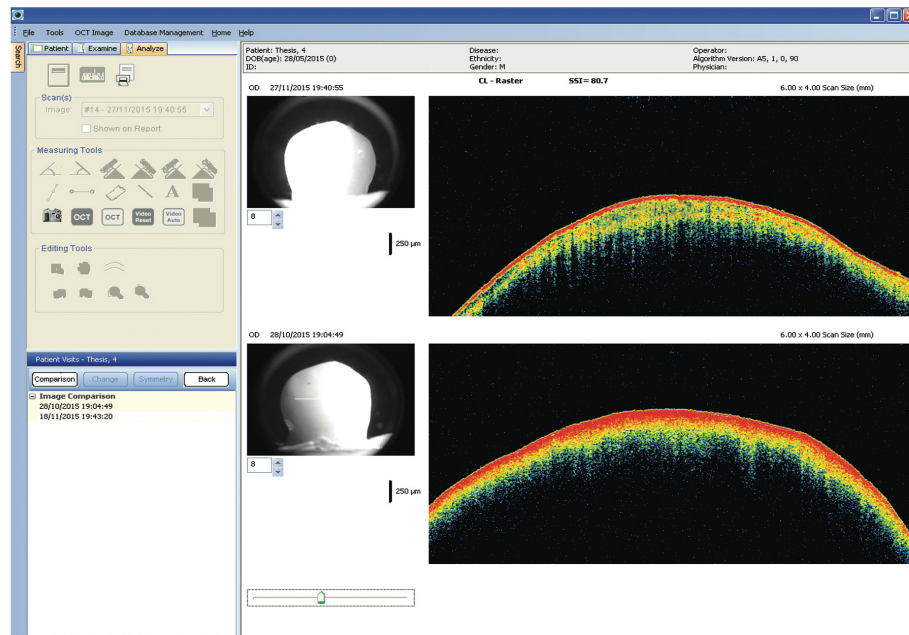


Table IV: Comparison of remaining adhesive layer in depth and area between low speed and high speed tungsten carbide bur clean up procedure under conventional etch and self etch adhesive system.

	Conventional Etch adhesive system		Self Etch adhesive system	
	Low Speed	High Speed	Low Speed	High Speed
RALD (μm)	50.125 \pm 16.16	58.883 \pm 11.69	37.706 \pm 6.5	44.508 \pm 16.11
F value	7.714**		5.637*	
RALA (mm^2)	0.104 \pm 0.03	0.123 \pm 0.04	0.079 \pm 0.03	0.099 \pm 0.03
F value	4.363*		10.027**	

* - significant at 0.05 level

** - significant at 0.01 level

Statistical analysis:

To identify differences in mean depth and the area of remaining adhesive under two main groups and two sub groups one way- analysis of variance test was performed (ANOVA).

Result:

This table indicates that there is a significant differences in the residual adhesive layer in depth and area between low speed tungsten carbide bur and high speed tungsten carbide bur clean up procedure under conventional etch adhesive system and self etch adhesive system respectively.

Chart IV: Distribution of remaining adhesive layer in depth and area between low speed and high speed tungsten carbide bur clean up procedure under conventional etch and self etch adhesive system.

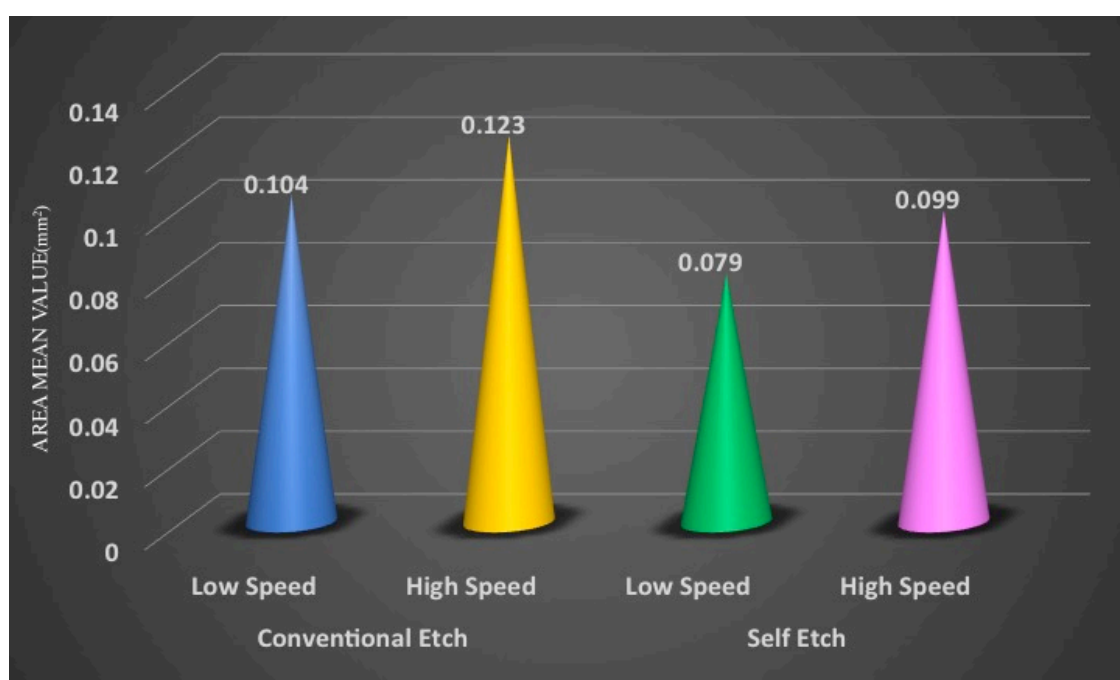
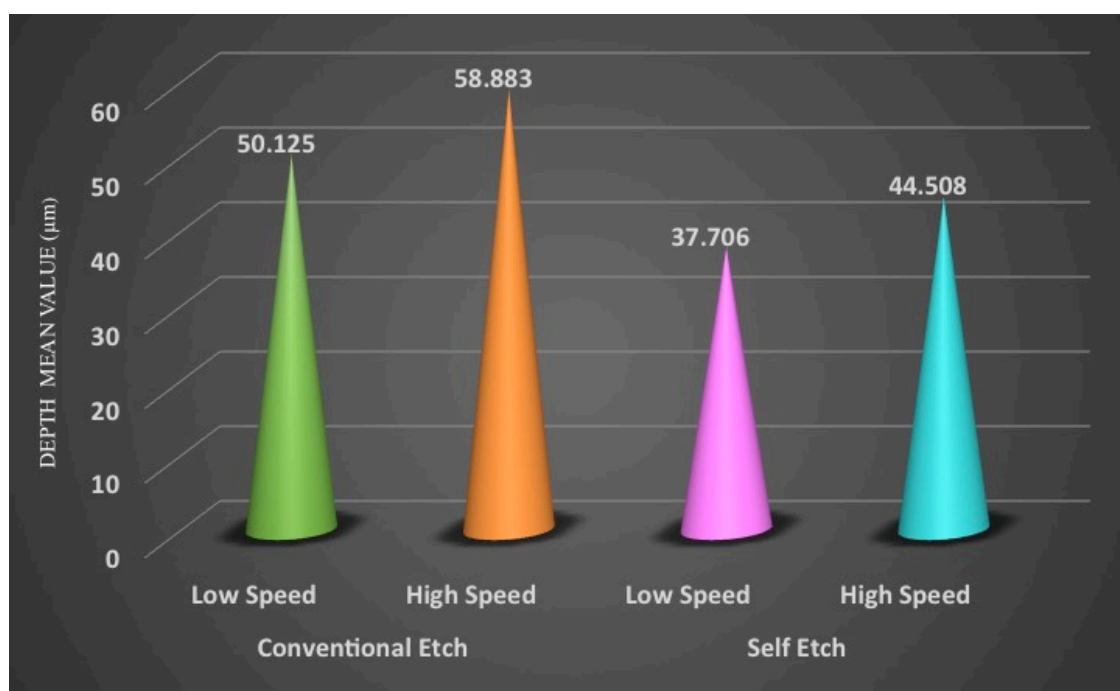


Table V: Comparison of remaining adhesive layer in area and depth post clean up under conventional etch and self etch adhesive system.

Groups	Mean of RALD (μm)	Mean of RALA(mm^2)
Conventional etch adhesive system	54.504	0.113
Self etch adhesive system	41.107	0.089
t-value	6.071**	4.228**

* - significant at 0.05 level

** - significant at 0.01 level

Statistical analysis:

To identify differences in mean depth and the area of remaining adhesive under two main groups Students 't' test was performed.

Result:

This table indicates that there is significant differences in layer of remaining adhesive in depth and area between self etch adhesive system and conventional etch adhesive system.

Chart V. Distribution of remaining adhesive layer in depth and Area between conventional etch adhesive system and self etch adhesive system post clean up

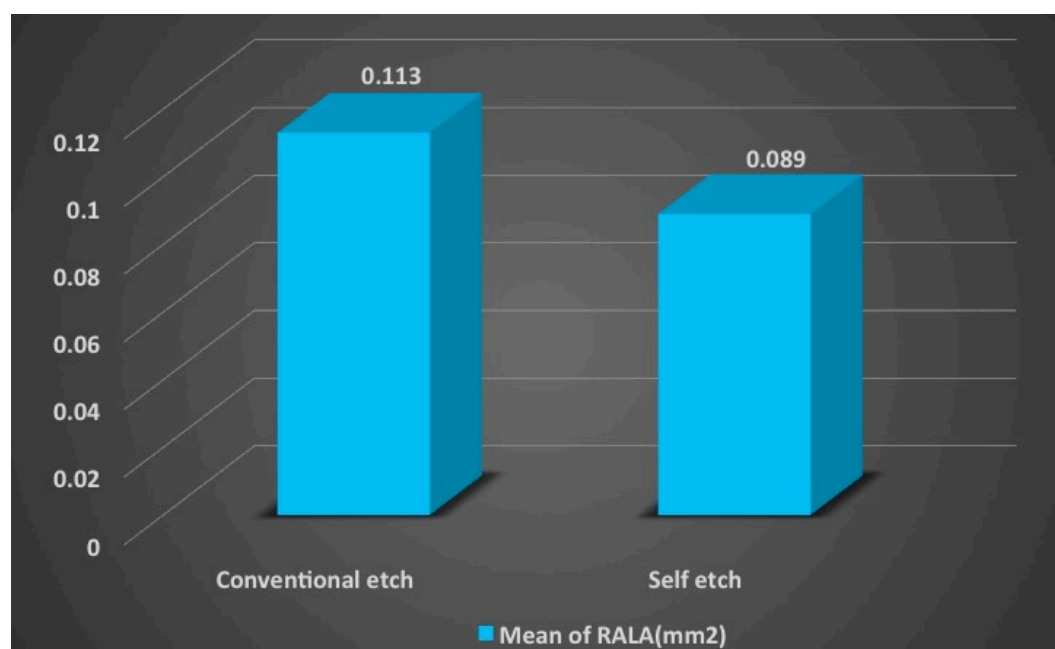
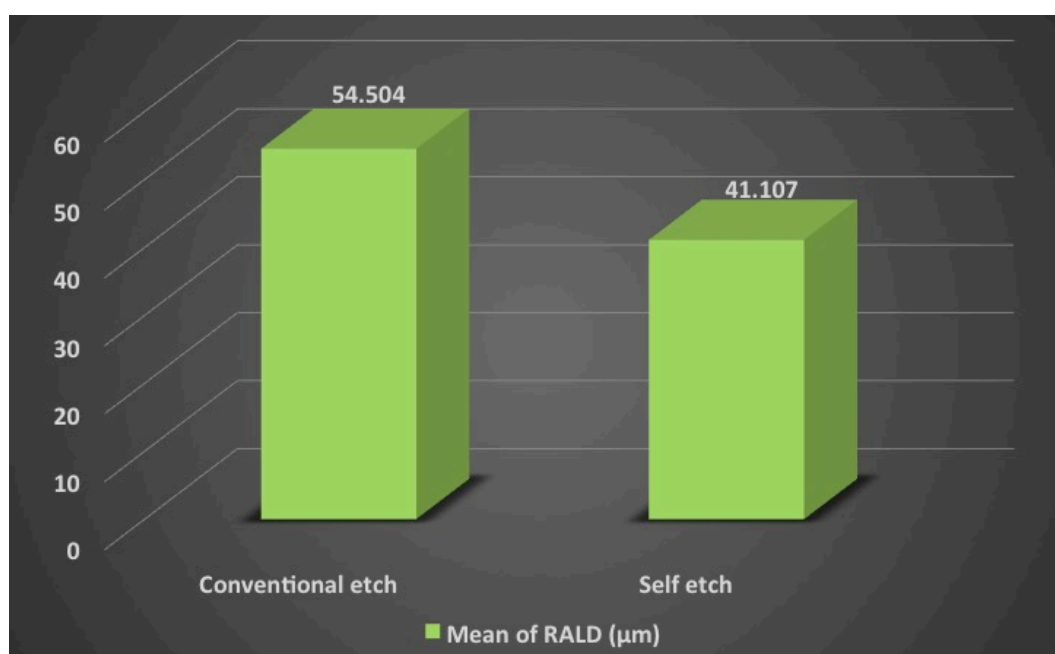


Figure 28: Measurement of remaining adhesive layer in area and depth post clean up for self etch adhesive system

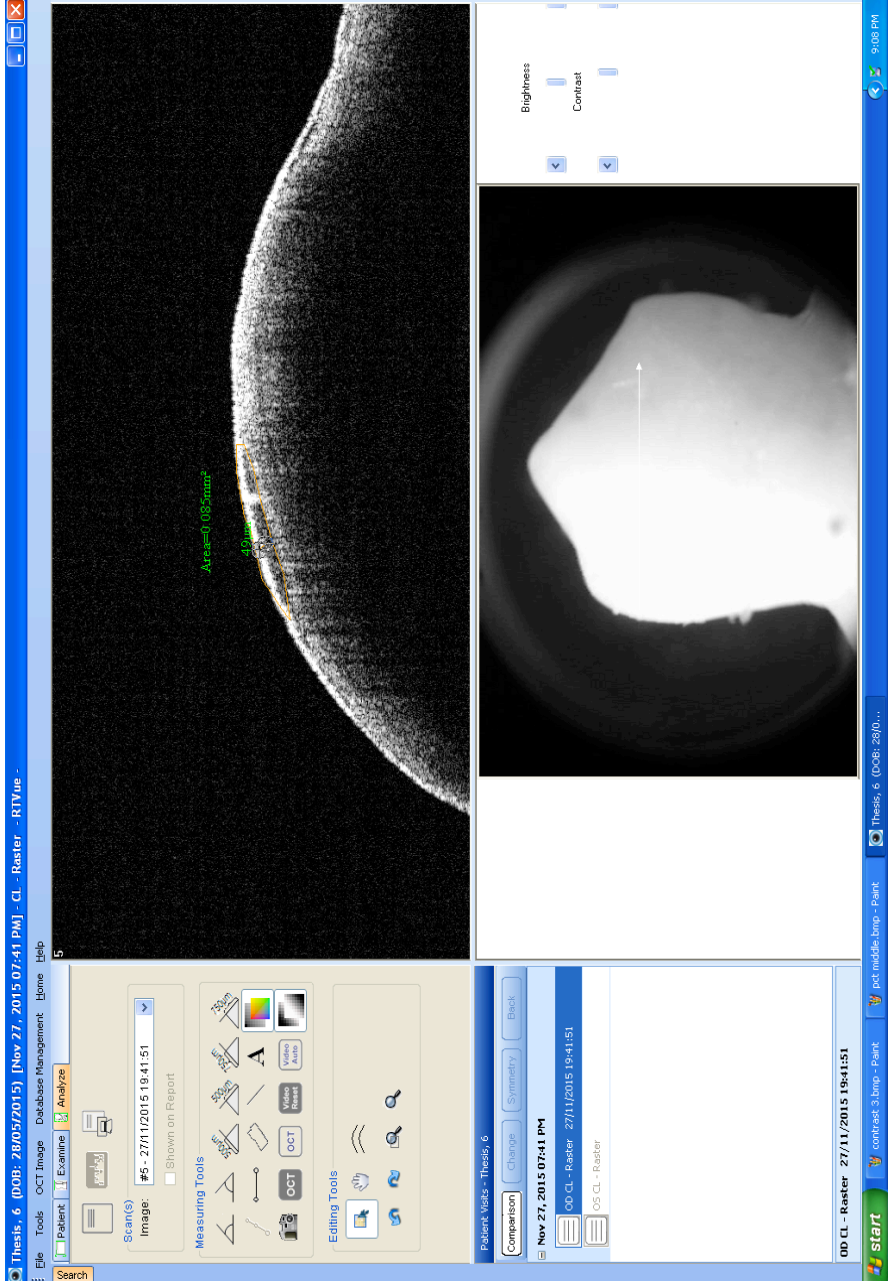
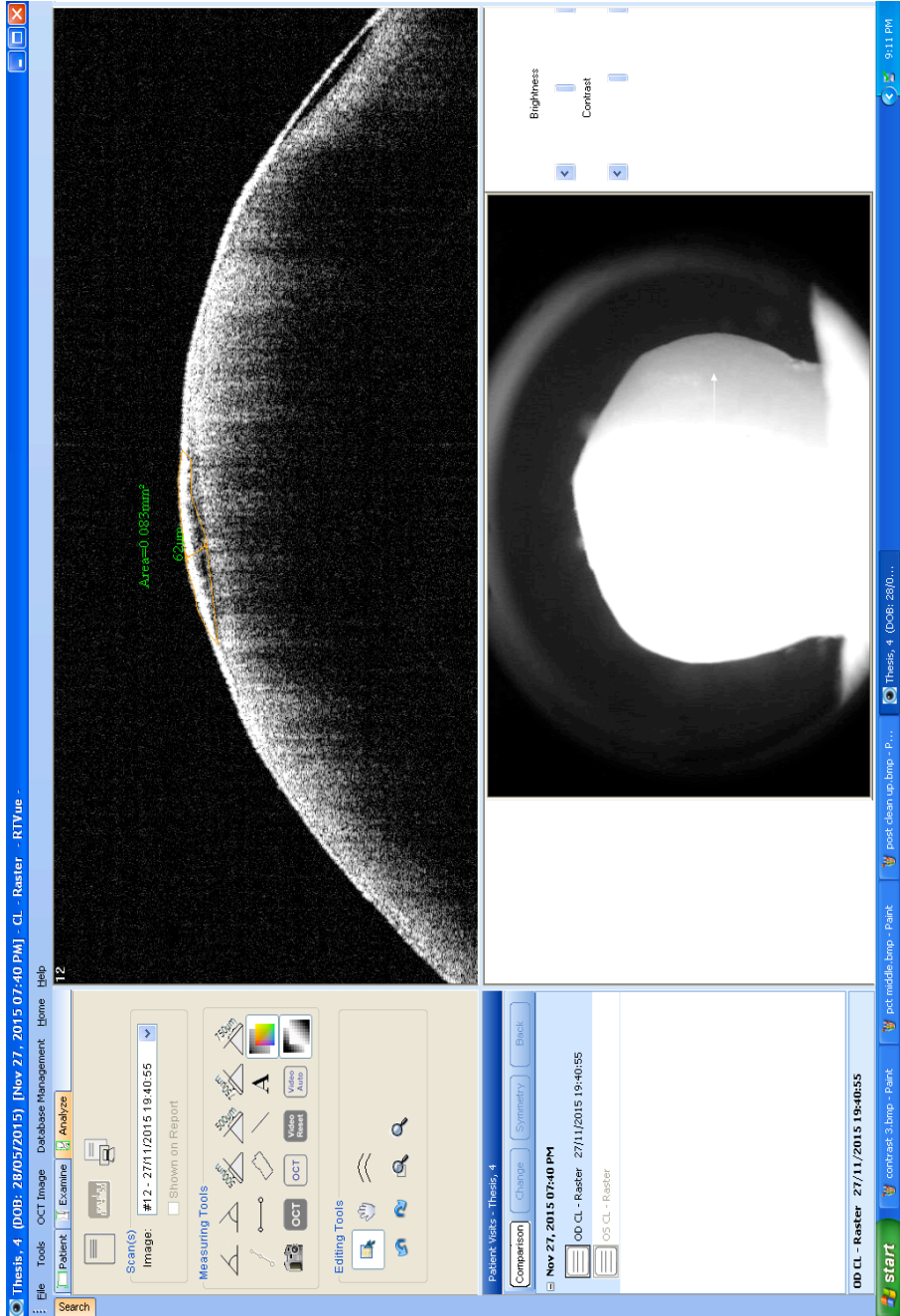


Figure 29: Measurement of remaining adhesive layer in area and depth post clean up for conventional etch adhesive system



It has always been the aim of an orthodontist to remove fixed appliances without leaving any residual adhesive or damaging the enamel. The amount of residual adhesive remnant and enamel damage depend on several factors right from choosing the type of adhesive system used to bond the bracket, type of bracket used, type of method used to debond the bracket and the type of bur used for clean up of the remaining adhesive.

Adhesion to enamel is achieved through acid etching of the highly mineralized substrate, which substantially enlarges its surface area for bonding. Transformation of surface enamel through etching creates a irregular surface with a high surface energy (72dynes/cm) more than twice that of unetched enamel. An unfilled or filled liquid acrylic resin with low viscosity wets the high energy surface and is drawn into the micro porosities by capillary attraction. The presence of hybrid layer formed by cured resin on the etched enamel has been the major factor responsible for enamel adhesion of resin-based composite.

Direct bonding of orthodontic brackets using 37% phosphoric acid etching technique is the most common technique in orthodontics. This creates a etch pattern characterized by a deep and uniform demineralized area later infiltrated by resin of the primer in the form of resin tags.

Cehreli and Altay⁶⁶ in a study found that irrespective of the treatment time, using 37% phosphoric acid results in irreversible damage of the enamel surface.

Recently there is increase in preferences for a milder form of etching procedures. **Julio P. Cal-Neto⁵** in a study observed that resin tag penetration were shorter in self etch group when compared to the conventional etch group (control). However, in the context of bond strength, the increase of surface area and the

rheological properties of the resin may be more significant than the depth of adhesive penetration. This can be inferred from previous laboratory investigations that self etch primer can successfully bond orthodontic brackets with clinically acceptable shear bond strengths of approximately 7.1 ± 4.4 MPa when compared to use of conventional acid etching (10.4 ± 2.8 MPa)³⁵.

So the use of self etch primer would have the advantage of combining etching and priming into a single step. In addition to saving time the fewer steps might minimize procedural errors and proved to produce a uniform and conservative etch pattern with regular adhesive penetration and less enamel dissolution.

Debonding of brackets using the debonding plier produces three types of failure:

- 1) Adhesive failure between the adhesive and the base of the bracket
- 2) Adhesive failure between the adhesive and the enamel
- 3) Cohesive failure between the molecules of the adhesive layer

The debonding is a procedure with a risk of damage to the enamel in the form of cracks, scratches or tissue loss. **Knosel et al**⁵¹ in 2010 and **Zacchrisson et al**¹⁰ in 1980 observed that maintaining the structural integrity of the enamel after debonding coincides with the presence of larger quantities of remaining adhesive.

Many studies have shown that debonding technique is directly related to the amount of remaining adhesive on the enamel surface. So, in this study the debonding technique that produces the least stress on the enamel was considered.

Knosel et al⁵¹ in his study also showed that lowest proportion of enamel damage were seen while using the bracket removing pliers than the lift off debonding instrument and the side cutters.

Bracket removing pliers use a bilateral force with its extensions placed on the wings or base of the bracket. Though structural deformation of the metallic bracket occurred, this was expected as we are considering the type of methodology that produces the least damage to the enamel. Thus the crucial point is the breakage line located within the bracket and the bracket adhesive interface thus maintaining the thin layer of adhesive over the enamel.

On the other hand, debonding techniques like using lift off debonding plier and side cutter plier produced a unilateral type of force rather than a bilateral type of force that enables the clinician less movement control thus the failure of the bracket was predominantly at the enamel/adhesive interface, which offers more risk to the enamel.

However, **Leao Filho et al¹³** in a recent study showed that both the side cutter and bracket removing plier generated larger amounts of remaining adhesive with the failure of the bracket mostly at the bracket /adhesive interface thus minimizing damage to the enamel. Hence this can explain why bracket-removing plier was used in the present study for debonding.

Enamel loss from debonding orthodontic brackets is usually assessed only after clean up. Residual adhesive on the enamel surface after debonding can be removed in various ways, but studies have shown that some recommended modalities damage enamel surfaces.

The difference in the cutting efficiency of rotary instruments may be determined by a number of parameters, including the bur rotation speed, the pressure applied to the hand piece during cutting, the type of bur and the flow rate of coolant through the hand piece at the bur/tooth cutting interface (**Siegel and von Fraunhofer, 1999**)⁶⁵. Cutting with carbide burs is primarily by plastic flow and flow- dependent fracture processes due to the high shear forces between the blades and the surface. These forces result in plastic ploughing of the surface, followed by brittle fracture adjacent to the furrows. Because material removal by a tungsten carbide blade occurs by flow- driven processes rather than brittle fracture, carbide burs are ideal cutting tools for ductile substrates such as resins.

Tungsten carbide burs are available in various sizes, shapes and different grits. The frequently employed ones have 8 -30 flutes, and predominantly 12- and 30-fluted burs are considered safe to use on enamel⁵⁷.

In a study, **Campbell et al**⁹ concluded that the materials that produced the best surface finish and with minimal enamel loss was a fluted tungsten carbide bur used in a high-speed handpiece, followed by rubber points and cups, a water slurry of fine pumice, and finally brown and green cups in a slow-speed handpiece. **Zachrisson et al**¹⁰ showed that enamel loss is minimized with the use of a spiral fluted tungsten carbide bur in a slow-speed handpiece.

Hence in the present study a comparison was made between low speed and high speed tungsten carbide bur.

The search for an efficient and safe method to achieve debonding procedure with minimal enamel loss has attracted the interest of many researchers and many studies have been published. Those studies, done to assess the enamel surface after

debonding and clean up were mostly surface assessment methods like scanning electron microscope and optical profilometry.

Very few studies provided quantitative in depth analysis within the enamel after debonding like study by **Suliman et al⁶ in 2015** where he used a three dimensional optical scanner to determine the amount of enamel loss in depth and volume.

Study by **Olszowska et al⁵⁷ in 2015** used a three dimensional blue light scanner to measure adhesive remnant and enamel loss quantitatively after debonding orthodontic attachments.

Thus, Optical coherence tomography a quantitative diagnostic tool as described earlier by **Filho et al¹³ in 2015** was used in this study to determine enamel surface changes caused by orthodontic bonding and debonding in vitro

Optical coherence tomography is a non-invasive medical imaging technique with a high quality resolution that can give near histologic image with a safe broadband light source.

It can be seen similar to ultrasound technique where the inspected reflected wave from the tissue acquires the structural information of the biological sample. The difference is that OCT uses light waves instead of sound waves.

Principle of OCT

Scattering is a fundamental property of a heterogenous medium and occurs because of variation in the refractive index within the tissue and OCT works on the principle of interferometry and scattering, which uses the technique of superimposing two of more interfering scattered waves and to detect the differences between them.

Two waves with a same frequency that have the same phase will add each other while two waves that have opposite phase will subtract.

Broad- band laser light waves are emitted from a source and directed toward a beam splitter. One wave is sent toward a reference mirror with a known path length and the other toward the tissue sample. After the two beams reflect off the reference mirror and the tissue surfaces at varying depths in the sample, the reflected light is directed back toward the beam splitter, where the waves are recombined and read with a photo detector.

There are two common types of OCT 1) Time domain optical coherence tomography 2) Spectral/fourier domain optical coherence tomography

1) Time domain optical coherence tomography (TD-OCT)

In TD-OCT, the scans are gradually built up over time by moving a mirror in the reference arm of the interferometer⁵⁵.

2) Spectral/fourier domain optical coherence tomography (SD-OCT)

In SD-OCT, information on depth is transformed from the frequency domain to the time domain, without using a moving reference mirror.

The advantage of SD-OCT is that it allows the image to be acquired rapidly, about 60 times faster than with TD- OCT and these devices use a central wavelength of 800–850nm a high-speed spectrometer that analyses simultaneously all the frequencies⁵⁵ (Figure: 20).

In dentistry, this technology has been applied to determine the anatomical characterization of dental and periodontal structures, detection of incipient caries,

evaluation of dental materials, determine qualitative markers of biofilm formed around the orthodontic brackets and evaluation of periodontal ligament responses to orthodontic forces.

Optical coherence tomography was used in this study to evaluate enamel surface changes because of the following advantages

1. It is a fast, non-invasive radiation free technique
2. Ability to visualize the tooth structures at the microscopic level
3. Teeth can be scanned directly without the need for gold sputtering and making plaster models
4. The information offered is detailed and easily interpretable.

In the present study Rtvue (Optovue) OCT unit which is a real time tracking OCT unit that uses Fourier /spectral domain system was used. The Rtvue scanner produces two types of images: enface and axial cross sectional (2D) images needed for the study and it is viewed in the preconfigured PC built in with the scanner. The software tools along with Rtvue software was used in the measurement of remaining adhesive layer in depth and area, and degree of enamel loss at various stages.

The purpose of this in vitro study was to quantify and compare the adhesive remnant and degree of enamel loss after debonding in order to compile and determine which procedure is minimally invasive to the enamel.

In the study, freshly extracted 160 premolars were taken and OCT scan was done to rule out samples that had cracks and subsurface demineralization.

The samples were categorized into two major groups, the metal and ceramic brackets further split into sub groups based on the type of adhesive system and type of

clean up process.

OCT scans were taken after debonding and after clean up, measurements were made and the data was collected and statistically analyzed.

For the ease of understanding, the discussion is categorized as follows:

Measurement of remaining adhesive layer in depth and area after debonding

The OCT scans allowed us to quantify layer of adhesive remnant both in area and thickness between the two bracket systems (metal and ceramic) under two different adhesive systems (Self etch system and conventional etch system) pertaining to the fact that both the choice of the bracket and choice of adhesive play a significant role on the amount of adhesive remnant on the enamel surface.

In this study the mean of adhesive remnant area for ceramic brackets was (1.222mm^2) and (0.967mm^2) which is significantly more than metal brackets which is (0.828mm^2) and (0.650mm^2) under self etch adhesive system and conventional etch adhesive system respectively. The mean of adhesive remnant in depth for metal and ceramic brackets did not significantly vary which is ($157.24\mu\text{m}$) and ($155.38\mu\text{m}$) under self etch adhesive system and ($160.63\mu\text{m}$) and ($160.14\mu\text{m}$) under conventional etch adhesive system respectively (Table: I, Chart: I).

The debonding of ceramic brackets occurs mainly because of failure at the enamel-adhesive interface²². Additionally, in most cases the debonding of metal brackets leads to a failure at the interface between the adhesive and the bracket base⁶⁸.

In the present study the ceramic bracket has more remaining adhesive area than metal brackets but the average thickness remained the same for both ceramic and metal brackets. On comparing the results with ARI index visually assessed and scored

based on the scoring system given by **Artun and Bergland in 1984**⁶⁷, where both the ceramic and metal brackets achieved a significantly larger score indicating there is a higher incidence of failure in the bracket adhesive interface for both ceramic and metal brackets under self etch and conventional etch adhesive system.

Thus the OCT image used in this study post debonding not only shows the difference between enamel and resin in depth by a thin demarcation line, it also allowed us to further quantify the remaining adhesive in area and depth which infers the fracture mode ultimately. Thus the present study on comparing the post debonding results with ARI index has provided an in depth clear analysis on which interface the bracket had fractured.

This is in agreement with the study done by **Filho et al 2015**⁶⁹ where he concluded that the type of bracket (metal or ceramic) did not influence significantly on the amount of remaining adhesive on enamel after debonding ($p>0.05$), indicating that there is a higher incidence of failure at the adhesive-bracket interface for both types of brackets.

Suliman et al⁶ in a study compared the effect of polycrystalline and monocrystalline ceramic brackets. He showed that almost all polycrystalline ceramic bracket fractured in two or more fragments while only one of the monocrystalline brackets fractured during debonding. Monocrystalline bracket are designed to peel off the tooth in one piece when debonded and the characteristic is due to zirconia microsphere's that are embedded in the base of the bracket.

So in the present study, reduction of thickness and increase in the area of the remaining adhesive may be attributed to the fact that the ceramic brackets used were monocrystalline ceramic brackets.

Measurement of degree of enamel loss post clean up

In this present study, OCT scans and Pachymetry mapping of the samples were done post clean up and we were able to categorize the samples in different ranges of enamel thickness (Table: III, Chart: III).

The ranges were selected based on the depth of penetration into the enamel surface by the OCT scanner (upto 800 μm) and they were sorted and tabulated. Here we have compared the degree of changes in the enamel loss between the preliminary scan and the post clean up scan taken in the study.

In this study the baseline enamel thickness ranged with a lower limit of 600 and a upper limit of 800 μm . On comparing between low speed and high speed tungsten carbide burs the post clean up enamel thickness were significantly less in the high speed tungsten carbide bur groups with enamel thickness more in the 600 -720 μm range and the low speed tungsten carbide bur showed enamel thickness in 760 - 720 μm range which shows that high speed tungsten carbide bur leads to more enamel loss when compared to low speed tungsten carbide bur.

This result is in agreement with the study by **Ingrid hosein et al**⁴ where they have shown that least enamel loss occurred after the use of low speed tungsten carbide bur.

The result of the present study is also in agreement with **Ireland et al**³⁸ who studied four different clean up methods under different adhesive systems, found that least enamel loss occurred following the use of the low speed tungsten carbide bur and the greatest loss was seen with the ultrasonic scaler or high-speed tungsten carbide bur.

Measurement of adhesive remnant layer in area and depth post clean up

Numerous studies have evaluated the characteristics of enamel surface after clean up procedure but only very few studies have analyzed the adhesive remnant in depth after clean up.

In this study after clean up, the adhesive remnant in depth and area for self etch and conventional etch groups under low speed tungsten carbide bur showed a mean value of (37.706 μ m, 0.079mm²) and (50.125 μ m and 0.104mm²) which is significantly less when compared to high speed tungsten carbide bur groups which was (44.508 μ m, 0.099mm²) and (58.88 μ m, 0.123 mm²) respectively (Table: IV, Chart: IV).

The mean of adhesive remnant in depth and area for self etch adhesive system was (41.107 μ m, 0.089mm²) which is significantly less when compared to conventional etch adhesive system (54.504 μ m, 0.113mm²) irrespective of the type of clean up procedure (Table: V, Chart: V).

Thus, in the present study the layer of remaining adhesive in depth and area were significantly lower for low speed tungsten carbide bur clean up procedure when compared to high speed tungsten carbide bur clean up procedure.

At the same time the self etch groups showed a significantly smaller amount of residual adhesive remnant in depth and area than conventional etch groups which was similar for the previous studies^{5, 48} where they have shown that self etch adhesive system groups exhibited a more conservative etch pattern, shorter remaining adhesive in depth and thereby reduced enamel dissolution than conventional etch adhesive system.

In addition to previous studies quoting about the advantages of self etching primers, for bonding orthodontic attachments, the present study has given an in depth analysis of remaining adhesive in depth and area post clean up proving that self etch adhesive system can be desirable not just because it causes less enamel dissolution with sufficient clinical bond strength but also they reduce clinical steps, save chair time, and reduce the risk of enamel discoloration after orthodontic treatment.

The result of our present study is in agreement with SEM study done by **Zachrisson and Arthun**¹⁰ where they have recommended using tungsten carbide burs at low speeds showing its superior accessibility into anatomical grooves and its efficiency in resin removal. **Van waes et al**³² in their study also recommended using tungsten carbide burs at low speed. **Filho et al**⁶⁹ in a recent study also found that the use of burs at low speed removes the remaining adhesive more effectively when compared to burs at high speed both in terms of depth and the area of the remaining adhesive layer.

The result of the present study inferred in relation to the type of clean up is not in agreement with study by **Rouleau et al**¹⁹ who found that tungsten carbide bur at high speed to be most effective in residual resin removal. However, SEM micrographs in his study clearly demonstrated that the enamel scarring is inevitable even with high-speed tungsten carbide bur clean up procedure.

Thus inferring from the result of this present study and previous literature, low speed tungsten carbide bur under self etch adhesive system can be used as a safe and efficient method for removal of adhesive remnant.

Limitations of the study

The present study is an in vitro study where intra oral conditions could not be simulated. Thus, values were taken without considering factors like saliva, masticatory forces, temperature and ph changes.

When evaluating the out come of this study, it is important to keep in mind that debonding under clinical conditions and consequent results may differ from the in vitro conditions. Debonding forces may be applied slightly differently, while temperature, moisture, and other oral conditions could reduce the bond strength and therefore alter the amount of adhesive remnant and enamel damage during debonding.

In spite of few limitations the present study successfully concluded that the usage of self etch adhesive system and clean up using low speed tungsten carbide bur minimizes the amount of residual adhesive remnant and damage to the enamel.

In the present in vitro study we have quantified and compared the adhesive remnant and degree of enamel loss after debonding and clean up under two adhesive systems using optical coherence tomography.

A commercial spectral domain optical coherence tomography system RT VUE (Optovue, Fremont, CA) which is a real time tracking OCT unit with a 5 μ m axial spatial resolution was used in this study. This machine is based on the Michelson's interferometer setup. It is connected to a preconfigured personal computer, and two images: enface and 2D axial cross sectional images were captured with a Rt vue scanner.

A total of 160 premolars, which followed the inclusion and exclusion criteria were bonded with metal and ceramic brackets under two adhesive systems. Quantitative analysis was done using OCT images to evaluate the layer of adhesive remnant in area and depth and damage to the enamel after debonding under two adhesive systems and two clean up procedures thereby allowing in depth analysis and comparison of the variables.

In context, the OCT system can be clinically applied to analyze remnant adhesive, enamel loss and has great potential for use in orthodontic research in the future. However, further efforts are still necessary to improve the technique and enable the clinical use of the technology.

Within the limitations of this present study the following conclusions were made:

1. After debonding, the amount of remaining adhesive was similar for both metal and ceramic brackets irrespective of the type of adhesive system used.
2. Enamel loss is more in high-speed tungsten carbide bur clean up procedure than low speed tungsten carbide bur clean up procedure.

3. Adhesive remnant in area and depth after clean up was less for self etch adhesive system when compared to the conventional etch adhesive system.
4. Adhesive remnant in area and depth was less for low speed tungsten carbide bur clean up procedure when compared to high speed tungsten carbide bur clean up procedure.

Hence, self etch adhesive system and low speed tungsten carbide bur clean up technique has shown to be promising in minimizing the damage to the enamel.

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ABBREVIATIONS

OCT	-	Optical Coherence Tomography
SD-OCT	-	Spectral Domain Optical Coherence Tomography
TD-OCT	-	Time Domain Optical Coherence Tomography
RALA	-	Remaining Adhesive Layer in Area
RALD	-	Remaining Adhesive Layer in Depth
SEP	-	Self Etch Primer
SBS	-	Shear Bond Strength
ARI	-	Adhesive Remnant Index
SEM	-	Scanning Electron Microscope
CLSM	-	Confocal Laser Scanning Microscope
ROI	-	Region of Interest